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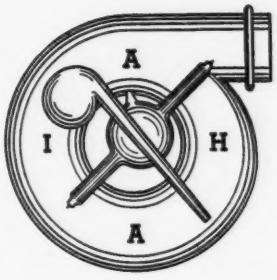

VOLUME 13 DECEMBER, 1952 NUMBER 4

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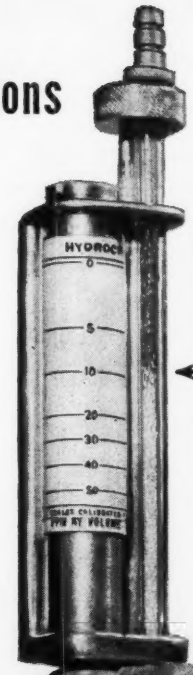

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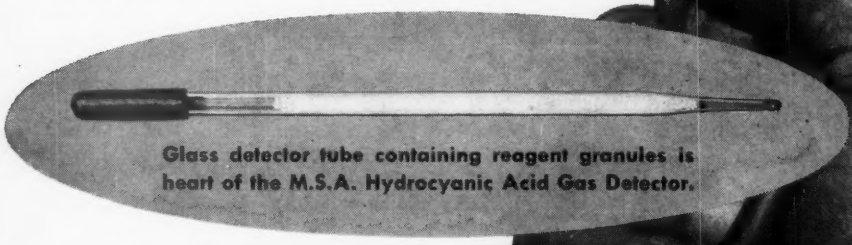
for an 8-hour exposure—American Conference of Government Hygienists



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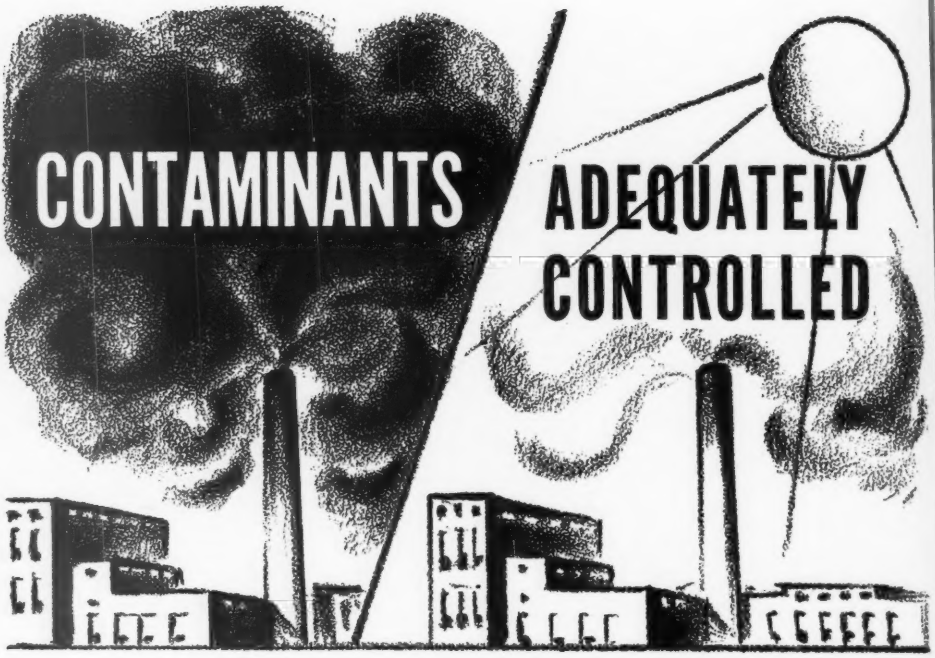

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Use of Thoriated Tungsten Electrodes in Inert Gas Shielded Arc Welding—

INVESTIGATION OF POTENTIAL HAZARD

A. J. BRESLIN and W. B. HARRIS
Industrial Hygiene Branch, Health and Safety Division
New York Operations Office, U.S. Atomic Energy Commission

THORIATED tungsten electrodes have gained widespread acceptance since their introduction several years ago, because of advantages which they possess over pure tungsten electrodes. The advantages which are generally accepted, are greater freedom from weld metal contamination, easier arc starting, greater arc stability and higher current-carrying capacity. Both ease of operation and economy are factors which contribute to their popularity.

Within the group of industries which manufacture, market and utilize welding equipment, a serious question has arisen recently about the alleged hazard associated with the use of thoriated tungsten electrodes for inert gas shielded arc welding. The basis on which rests the suspicion that a hazard may exist is that thorium oxide, an ingredient of the electrode, possesses natural radioactivity.

The electrodes in greatest use normally contain from 1% to 2% of thoria (thorium oxide). Tungsten electrodes used in inert arc welding are generally considered to be non-consumable. Actually, however, the rate of consumption, although very low, is appreciable. This consumption may be of the order of from 0.1 to 0.3 milligrams per minute for nominal currents. At the maximum rated current and over long welding periods, the rate of consumption of a given diameter electrode may be increased and has been found to run as high as 50 to 60 milligrams per minute. The mechanism of electrode consumption probably includes volatilization and also the loss of small droplets of metal at the tip where the heat is very intense. If one assumes that the thoria is uniformly distributed throughout the length of the electrode, the rate at which radioactive thorium is released is proportional to the rate of electrode consumption. It is reasonable to assume that a substantial portion of the radioactivity coming from the electrode becomes airborne through volatilization. If this is the case, a potential hazard to the welder and to other occupants of the room due to inhalation of the radioactive material is possible.

This potential hazard associated with the use of thoriated tungsten electrodes, coupled with the many advantages which they possess, poses a dilemma both for the producers and for the users of this equipment.

Several months ago, the Health and Safety Division of the New York Office, Atomic Energy Commission, was consulted by one of the NYO contractors regarding the potential hazard in the use of thoriated tungsten. This contractor was contemplating an extensive use of inert arc welding and requested recommendations of appropriate precautions. Since the Health and Safety Division did not have nor could find specific information on the subject, an investigation was launched. This investigation was made possible through the cooperation of a local manufacturer of welding equipment that made available laboratory facilities. The general scope of the project was to determine whether the use of thoriated tungsten electrodes creates a hazard due to radioactivity and if so, to formulate recommendations for protective measures.

The experimental work was conducted in the manufacturer's laboratory workshop. Standard inert gas welding equipment was used. Equipment was operated by an experienced welder. The manufacturer's

recommendations were followed in selecting welding conditions under which the tests were to be conducted. Generally, common commercial applications were selected and in most cases, maximum rated currents were employed to create the most severe conditions. In the tests, electrodes of 3/32" and 5/32" diameter were used. Both nominal 1% and 2% thoria electrodes of the 3/32" size were tested. Of the 5/32" electrode, nominal 2% thoria only were used. These electrodes had been produced by powdered metallurgy techniques, using a thorium compound mixed uniformly with tungsten oxide, and were formed by sintering followed by swaging.

Measurements were made to establish two things—(1) concentrations of activity in the vicinity of the welding operation and specifically in the breathing zone of the operator, and (2) the rate at which radioactive material was released into the air from the arc. No ventilation was applied to the process while breathing zone and general air samples were collected. Natural ventilation was baffled as much as possible to reduce air movement in the area.

Airborne Radioactive Materials

RADIOACTIVE dust was sampled by drawing the air through a 1⅛" diameter, Whatman No. 41 filter paper at a rate of 0.020 cubic meters per minute. Air flow was measured by a variable orifice air flow meter. This equipment is standard in this office for obtaining samples of this type.

In the collection of breathing zone samples, the filter holder was connected to the pump assembly by a flexible tubing so that the motions of the welder could be followed with freedom. The filter head was held at the lowest part of the welder's protective shield. General air samples were obtained either by suspending the pumps above the arc or by clamping them in fixed, lateral positions relative to the arc. The filters were analyzed for alpha activity in alpha scintillation counters. Each sample was counted twice—once within 24 hours of collection and again several days later. The first count was made in order that short-lived activity due to thoron daughter products could be estimated and the second count to check long-lived alpha activity.

The results of the breathing zone tests are summarized in Table I. It should be noted that in all these samples, there was no significant activity detectable on the filter papers. The counts were in no case significantly higher than the blank samples used to indicate the background of the analytical equipment. Thus, all results which are recorded are presented as less than a given value. This is determined by the total volume of air filtered, the length of time the samples were counted and the statistical variability of the equipment. For tests 8, 9 and 10, longer sample periods

TABLE I.
SUMMARY OF BREATHING ZONE TESTS
All Electrodes Nominal 2% Thoria

Test Number	Electrode Diameter (inches)	Current (amperes)	Rate of Argon Flow (C.F.H.)	Material Welded	Welding Condition	No. of Samples	Av. B.Z. Conen.[4] α dis./min./M³
1	3/32	250 a.c.	18	aluminum	normal[1]	3	<13
2	3/32	250 a.c.	18	aluminum	contaminated electrode[2]	3	<33
3	3/32	250 d.c.[5]	18	mild steel	contaminated electrode	3	<10
4	3/32	250 d.c.	18	mild steel	oxidized electrode[3]	3	<5
5	3/32	250 d.c.	18	mild steel	oxidized contaminated electrode	3	<21
6	5/32	350 a.c.	30	aluminum	oxidized electrode	1	<1
7	5/32	350 a.c.	30	aluminum	normal	3	<17
8	3/32	250 a.c.	18	aluminum	normal	3	<0.9
9	5/32	400 d.c.	30	stainless steel	contaminated electrode	2	<0.9
10	5/32	400 d.c.	30	stainless steel	normal	3	<0.9

[1]After the arc was struck, the electrode was maintained at a uniform distance from the weld puddle.
[2]During the welding period, the electrode was brought in contact with the weld puddle approximately once/min.
[3]The electrode had been oxidized before use by prematurely turning off the argon flow after the previous welding period.
[4]The activity on the filter in every case was less than one count per minute and is not considered significantly higher than the scintillation counter background.
[5]Straight polartiy for all d.s. tests.

TABLE II.
SUMMARY OF GENERAL AIR (G.A.) TESTS
Tests 1 through 4, nominal 2% thoria
Tests 5 and 6, nominal 1% thoria

Test Number	Electrode Diameter (inches)	Current (amperes)	Rate of Argon Flow (C.F.H.)	Material Welded	Welding Condition	Position of Samples Relative to Arc	No. of Samples	Av. G.A. Conc. α dis./min./M^3
1	3/32	250 a.c.	18	aluminum	contaminated electrode	6" laterally	3	1 sample 210 2 samples <100
2	3/32	250 d.c.	18	mild steel	contaminated electrode	6" laterally	3	173
3	3/32	250 d.c.	18	mild steel	oxidized electrode	6" laterally	3	63
4	5/32	400 d.c.	30	stainless steel	contaminated electrode	20" above	3	<1.4
5	3/32	240 a.c.	18	aluminum	normal	4 simultaneous samples, 3 at 6" laterally, 120° apart and 1 10" above arc	3 sets of 4	10 (2) 8.9(1) <8.9(9)
6	3/32	240 a.c.	18	aluminum	normal	4 simultaneous samples, 3 at 12" laterally 120° above arc	3 sets of 4	11 (1) 17 (1) <8.9(10)

were employed and the samples were counted for longer periods. As a result, the data could be reported as less than 0.9 alpha disintegrations per minute per cubic meter. Tests 1 through 7 must be reported as less than a higher value because of the statistics. These higher numbers do not necessarily represent higher concentrations although the values may have been as high as the numbers quoted.

A summary of the general air samples is presented in Table II. In several cases, there was measurable activity on the filter papers. In the case of those samples reported as less than a given figure, the same interpretation should be applied as described for the breathing zone samples. In those samples on which measurable activity was found, no difference could be detected between the first and second counts so it may be concluded that there was no significant short-lived alpha activity (indicative of thoron and its daughters).

Rate of Thorium Release

THIS GROUP of samples was collected with a High Volume Sampler in which air is drawn through a 4" diameter filter paper. Volume of flow, as before, was measured by means of a variable orifice air flow meter. In this equipment, no adjustment of air flow is possible and, therefore, the rate of flow depends on the type of filter used and the quantity of dust deposited on the filter. For the tests, two types of standard, commercial respirator filters were used. One is designated as Bureau of Mines approved paper BM-2133 of the Mine Safety Appliance Company and the other is Type S, unimpregnated, pleated filter of the same manufacturer. The air flows through each of these filters when clean averaged one and two cubic meters per minute, respectively (35 c.f.m. and 70 c.f.m.).

In each test, the electrodes were weighed before and after the welding period and were also analyzed for thoria content. By this means, the quantity of thoria lost from the electrode was determined gravimetrically. During the welding period, samples were collected to measure the total amount of airborne activity. Two techniques were employed:

1. The first method was to sample the air discharged from a small, local exhaust system, which was considered to remove virtually all of the fume produced at the arc. No visible fumes were observed to escape the influence of the exhaust system during the welding. The rate of air flow in the exhaust system was measured and with the known sampling rate, the total quantity of activity released by the burning

electrode could be computed. Ideal isokinetic sampling conditions were not achieved.

2. The second method used was to replace the centrifugal fan of the exhaust system by two High Volume Samplers operating in parallel. These two samplers moved a combined air quantity which approximately equalled that produced by the exhaust system fan. Although this was true at the beginning of the sampling period, after several minutes of welding, the rate of air flow decreased because of the dust load which was deposited on the filters and the capture of fumes could not be considered to have been complete. However, each test was terminated as soon as visible fumes escaped from the influence of the exhaust hood. Therefore, it is believed that the activity measured on the filters was very nearly equal to the total activity released by the arc in the fume.

The samples which were taken during both of the tests described above were ashed and analyzed on alpha scintillation counters.

The results of these tests are tabulated in Table III.

The total quantity of thoria, as determined by sampling, is reported in milligrams. The conversion factor from weight to alpha activity is 0.001 milligrams equals one alpha disintegration per minute. Second counts given the samples in no case varied significantly from the first so that again it may be concluded that short-lived activity was negligible.

Permissible Concentrations

MEAGER INFORMATION is available concerning the toxic effects of thorium and its compounds. This material has been used commercially for many years, principally in the manufacture of gas lamp mantles. It had not been recognized as a potentially hazardous material. Recently, because of a recognition of its radioactive nature, its potential hazard has been questioned and some investigation of this hazard has been carried out. Because the AEC has an interest in thorium, the Health and Safety Division of the New York Office has been conducting investigations of occupational exposures and plant medical records in plants with long histories of thorium use in order that a realistic maximum permissible dust concentration may be selected. In the interim, however, it has been necessary to adopt a value toward the achievement of which engineering controls could be developed for use in Commission installations. The plant studies which have been completed to date, have offered no evidence that this figure underestimates the hazard, but rather, if anything, that the figure is conservative.

Thorium like uranium is a "heavy metal." Like uranium, the specific activity of thorium is very low. In general, the two materials can be said to possess similar radioactive characteristics. In radioactive equilibrium, both materials are primarily alpha emitters, and both decay through a gaseous daughter. Because of these similarities, it

TABLE III.
SUMMARY OF MEASUREMENTS OF TOTAL ACTIVITY
Tests 1-6, nominal 2% thoria—fan discharge sampled
Tests 7-9, nominal 1% thoria—total effluent collected in filters

Test Number	Electrode Diameter (inches)	Current (amperes)	Rate of Argon Flow (C.F.H.)	Material Welded	Welding Condition	Welding Period (min.)	Total Quantity of Thoria Lost—by Gravimetric Determination (mg)	Total Quantity of Air-borne Thoria—Measured by sampling (mg) (1 mg = 1000 α dis./min./M³
1	3/32	250 a.c.	18	aluminum	normal	8	1.07	0.49
2	3/32	250 a.c.	18	aluminum	normal	10	1.58	1.30
3	3/32	250 a.c.	18	aluminum	normal	10	0.30	0.93
4	3/32	250 a.c.	18	aluminum	normal	10	—*	2.93
5	3/32	250 a.c.	18	mild steel	contaminated electrode	9	4.01	1.92
6	3/32	250 a.c.	18	mild steel	contaminated electrode	6	7.14	1.24
7	3/32	240 a.c.	18	aluminum	normal	5	0.56	0.05
8	3/32	240 a.c.	18	aluminum	normal	2	0.04	0.03
9	3/32	240 a.c.	18	aluminum	normal	5	0.02	0.03

*Tip of electrode broken off before final weight was measured.

has been considered to be reasonable to suggest that the M.A.C. for thorium be identical with that for uranium on an equivalent activity basis. This value of 70 disintegrations per minute per cubic meter of air has been adopted by this office as an interim figure until a more basic value can be accepted. It should be noted that this value assumes an exposure of 40 hours per week for a working lifetime.

Evaluation of Air Samples

THE VALUE for the maximum permissible concentration which was discussed above was exceeded only in samples taken at a distance of 6" from the arc as shown by the general air samples. In the worst case this value was exceeded by a factor of three. In no case did any breathing zone sample approach the maximum allowable; the highest value being less than 33 d/m/M³. It should be pointed out that this value is computed and represents the statistical maximum to which the concentration may have gone. Actually this value could be anything between 0 and 33 d/m/M³.

Conclusions

1. When thoriated tungsten electrodes are used to generate an arc, radioactive thoria is released from the arc and becomes airborne as a fume. The rate of release is a direct function of the rate of electrode consumption, which in turn depends on such factors as current flow, electrode diameter, and welding technique. Air samples collected to measure total activity released, agree reasonably well with gravimetric determinations. During a 10 minute test a maximum value of 2.9 mg of thoria was released from a 3/32" diameter nominal 2% thoria electrode. This is roughly equivalent to 290 α d/m/m of arc time. The current density was the maximum rate for the size of the electrode which was used.

2. The activity released is sufficient to exceed the maximum permissible concentration at a distance of 6" from the arc. All general air samples collected 12" from the arc, or beyond, were 10 d/m/M³ or less with the exception of two (11 and 17 d/m/M³).

3. The activity which is released in the fume is sufficiently diluted by normal convection currents that the concentration at the breathing zone of the operator is well below the maximum allowable. No detectable activity was found in any of the breathing zone samples. Values reported as "less than" represent the maximum statistical probability based on the total air volume collected and the time of sample count. Eight of the samples were collected and counted for a sufficiently long period to represent the results as less than 0.9 d/m/M³.

4. The tests which were covered included a variety of commercial welding techniques. In general, high current densities were employed to simulate the most adverse conditions of fume dispersion. None of these techniques produced sufficient radioactivity in the breathing zone of the operator to be considered a hazard if an M.A.C. of 70 d/m/M³ is accepted.

5. It cannot be stated conclusively that under no circumstances would the maximum permissible concentration be exceeded. It is conceivable that the use of this equipment in a small totally enclosed space might result in excessive concentrations.

6. External radiation from the handling of these rods in any practical quantity is insignificant.

7. One type of welding which was not tested in this investigation was reverse polarity, direct current welding. It has been suggested that because of elevated electrode temperatures, high initial activities could be released from the rod. It is believed, however, that this would be a transient phenomenon.

8. It may be concluded that within the limits of the test which has been conducted inert gas welding using thoriated tungsten electrodes may be employed with no significant hazard to the operator or to other room occupants. Special ventilation or protective equipment is not indicated for the protection from radioactive fumes.

Acknowledgment

The assistance lent by the Development Laboratory of The Linde Air Products Company, Newark, New Jersey, made possible the tests described above. The active cooperation of Mr. W. B. Sharav of The Linde Air Products Co. and Dr. G. Nelson of the Union Carbide and Carbon Corp. is greatly appreciated.

Gases Produced by *Inert Arc Welding*

JOHN J. FERRY and GORDON B. GINTHER, Industrial Hygienists
Schenectady Works Hospital, General Electric Company

THE HEALTH hazards associated with welding processes were investigated quite thoroughly 10 to 20 years ago and were shown to be comparatively minor under normal conditions. Since that time several new welding processes, such as inert arc, atomic hydrogen, submerged arc, and arc welding with low-hydrogen type coatings, have come into common usage and the potential hazards have never been thoroughly investigated. The increasing importance of these processes is best illustrated by the fact that 30% of the country's production of helium is used by industry, mostly for inert arc welding.[1]

An investigation of gases and vapors which may be produced by the inert arc welding process has been made. Two different problems were investigated, the formation of ozone and nitrogen oxides, and the decomposition of trichloroethylene vapor in the vicinity of the arc. This latter condition was studied due to the fairly common procedure of degreasing materials prior to welding and because of the complaints which frequently arise when this is done.

Sampling Procedures

BECAUSE OF difficulties involved in prolonged sampling in the shops, all tests were made in the welding laboratory. The standard inert arc holder and power source was used. The power was direct current and straight polarity. The electrode was tungsten and the arc was struck to a water cooled copper block. During tests the electrode holder was clamped to maintain an arc of normal length. No filler metal was used, tests being made only on the effect of the arc. Welding grade helium and argon were used of 99.99% and 99.98% purity respectively, at a rate of 15 cubic feet per hour. In some cases normal gas flow was doubled to determine if this produced any unusual effect.

The currents tested, 55 and 110 amperes with 40 mil and 3/32 inch electrodes, were selected as those most commonly used in this plant. In the trichloroethylene decomposition tests, 110 amperes was used exclusively.

Ozone samples were collected by means of a fritted glass bubbler containing 30% potassium iodide, and ozone determined by titration with .01 N sodium thio-sulfate.[2] Although higher oxides of nitrogen may interfere with this method, it was felt that the results would, if not accurate, at least be on the high side. Sample volumes were approximately 500 liters collected over a period of eighteen minutes.

Oxides of nitrogen samples were collected by aspirating air into a four liter bottle. Acid peroxide was placed in the bottle and the determinations made by the phenol disulfonic acid method.[3] Both the above type samples were collected in the approximate breathing zone of the welder, at a point one to two feet from the arc.

TABLE I.
OZONE AND NITROGEN OXIDES

Gas Used	Amperage	Ozone in PPM	Nitrogen Oxides In PPM
Argon	55	0.1	
Helium	55	0.1	
Argon	110	0.5	
Argon	110	0.6*	
Helium	110	0.1	
Helium	110	0.1*	
Helium	110	0.0*	0.3*
Argon	110	0.4	2.5
Argon	110	0.6	3.0*
Helium	110		0.5*
Helium	110		0.3
Argon	110		3.0*
Argon	110		2.5

*Normal rate of gas flow was doubled.

For trichloroethylene decomposition, a cardboard box 16 inches on each side, was placed with the open side toward, and about 12 inches from, the arc. An evaporating dish containing trichloroethylene and varying numbers of paper wicks was placed in the box. Adjustment of these wicks permitted a fair degree of control of the vapor concentration. Three plastic sampling tubes were admitted through holes in the top of the box and extended to about three inches from the top. One of these tubes was connected to the Davis Halide Meter, and the values noted on the meter interpreted as the total trichloroethylene available at this point in the box. Immediately adjacent to the first tube, a second tube was connected to a fritted glass bubbler and to a suction pump. Before the arc was started, the pump was operated at a rate of 28 liters a minute and the desired vapor concentration established. Samples were collected for approximately 18 minutes in standard alkali and the resulting solution back titrated with standard sulfuric acid to determine total acidity. The solution resulting from titration was then made distinctly acid, silver nitrate added, and the silver chloride determined gravimetrically.

Phosgene was determined by the method described by the Department of Scientific and Industrial Research of Great Britain.[4] The efficiency of the scrubber to remove hydrogen chloride, etc., was checked after each series of tests. The specificity of these tests was confirmed by test papers using the Nitroso reagent.[5] Phosgene samples were initially collected at a point in the lower front edge of the box, on the theory that the results would be too low to be important. Because of the astonishingly high values found, these tests were repeated, sampling from the third tube adjacent to the Halide Meter with closer correlation to trichloroethylene concentrations. The results of the second series of tests are shown in Table III.

TABLE II.
TRICHLOROETHYLENE DECOMPOSITION

Gas Used	Trichloroethylene In PPM	Total Free Acidity*	Chlorides*	Phosgene** In PPM
Argon	30	56.0	31.0	35
Helium	30	4.0	3.0	4
Argon	300	168.0	90.0	350
Argon	25	1.0	1.0	3***
Argon	25	70.0	35.0	130
Argon	0-10	20.8	10.6	175

* Calculated as milligrams of hydrogen chloride per cubic meter of air sampled.

** Phosgene values are not directly related to trichloroethylene concentrations.

*** Arc shielded from trichloroethylene by glass funnel.

TABLE III.
PHOSGENE

Gas Used	Trichloroethylene In PPM	Phosgene Produced In PPM
Argon	0-15	45
Argon	60	140
Argon	100	180
Argon	140	280
Helium	30	6
Helium	30	4

Observations

DURING the tests for ozone, its odor was very distinct but not objectionable nor irritating.

No typical ozone odor was noticed during the trichloroethylene tests. There was, however, a very strong, irritating and disagreeable odor, somewhat reminiscent of trichloroacetic acid. This odor was produced even at a distance of several feet the instant the arc was struck when trichloroethylene vapor was present in the general atmosphere. The odor was not produced when the ordinary metallic arc was used in the presence of trichloroethylene. When a Pyrex glass funnel was placed between the arc and the trichloroethylene, no such odor was noticed.

Discussion

OZONE AND NITROGEN OXIDES: The results indicate that the ozone concentrations, while within the range that are sometimes considered irritating, were below the generally accepted threshold limit of one part per million. The oxides of nitrogen were well within safe limits. Whether these results would also be true for other forms of inert arc welding, using reversed polarity and alternating current, will have to be established experimentally. Results do indicate that higher amperage will probably increase ozone formation.

It is interesting to note that in every case argon produced more ozone, nitrogen oxides and trichloroethylene decomposition products, than did helium. An increase in gas flow gave a similar though much small-

er increase. It is felt that these latter phenomena are related to spectra of the respective gases. Unfortunately no information appears to be available in the literature to prove or disprove such a theory. Recent work in the field of analytical spectroscopy does indicate a greater intensity of emissent energy when an arc is operated in a helium or argon atmosphere,[6] and helium is known to have a much greater spectral emmission and absorption than argon in the ultraviolet range.[7]

TRICHLOROETHYLENE DECOMPOSITION: Trichloroethylene vapor in the vicinity of the arc was decomposed, the reaction starting instantly the arc was struck. While the correlation between trichloroethylene concentration and phosgene shown in Table III is obviously inaccurate, presumably because of limitations of the analytical methods used, the results do indicate that a large amount of the trichloroethylene is converted to phosgene. Other decomposition products were not identified. It is assumed that hydrogen chloride was present, but it is interesting to note that the total free acidity was just about twice that accounted for as hydrochloric acid by gravimetric determination of the chlorides. It appears that either a non-halogen acid or a halogen acid such as chloroacetic which is not readily hydrolyzed was also present.

It is easy to conceive of a shop atmosphere containing 20 to 30 parts per million of trichloroethylene, well below the threshold of odor, as a result of degreasing or other cleaning processes. It would not be unreasonable to assume, particularly if argon is used, dangerous concentrations of phosgene or other vapors being produced. Fortunately, the objectionable, irritating odor produced at the same time would probably discourage even the hardiest welder from continuing long on the job.

Shielding of the arc by means of a Pyrex glass funnel practically eliminated the decomposition effect. When a small amount of trichloroethylene vapor in a sealed quartz tube was exposed to the radiation of a therapeutic ultraviolet lamp for a few seconds, decomposition took place with acid and phosgene being produced, accompanied by the same odor formed at the arc. It is apparent that the action is photochemical with decomposition being caused by radiation from the arc, rather than by actual contact of the trichloroethylene vapor with the arc. This fact is of particular importance in providing control measures. It would appear that local exhaust ventilation at the arc would be of little value, since in the presence of even minute quantities of trichloroethylene, the decomposition products would be produced at the welder's breathing zone. Possibly a partial shield around the arc to prevent spread of radiation would be of greater value.

Conclusions

OXIDES of nitrogen were not produced in significant concentrations by the inert arc welding process studied.

Ozone was produced in significant concentrations, possibly in the irritating range, but below the threshold limit of 1 PPM.

Trichloroethylene vapor was decomposed, producing phosgene and other products. Such decomposition may produce dangerous concentrations of vapors from trichloroethylene concentrations well below the odor threshold.

The use of argon rather than helium in the torch significantly increased the formation of ozone, nitrogen oxides, and trichloroethylene decomposition products.

The reaction producing the various vapors and gases determined appeared to be photochemical, caused by radiation from the arc. This should be considered in planning control measures.

This investigation was made possible through the advice and assistance of the Welding Section, Schenectady Works Laboratory.

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BURNING RADIOACTIVE WASTES

in institutional incinerators

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THE NUMBER of isotope shipments has increased from about 200 in 1946 to almost 8000 in 1951. Most of these shipments were made to institutions studying medical therapy and animal physiology, with shipments of I-131 and P-32 far exceeding all others. The problem of disposal of radioactive waste materials in institutions is therefore becoming widespread.

A considerable portion of the activity finds its way into materials normally disposed of by incineration, such as the cage cleanings of experimental animals, egg embryos, and paper used for cleaning up spills and for other purposes in connection with laboratory work. Burning of these wastes in an existing incinerator is an attractive method of disposal, if it can be done without creating health hazards.

The study of the behavior of institutional incinerators when used to burn radioactive wastes was undertaken, therefore, in order to obtain information which would aid in setting safe limits and formulating standards of operation.

The Atomic Energy Commission has had considerable experience with incinerators designed especially to burn radioactive materials. These have all had gas filters and ash dust control devices. This report applies only to the usual type institutional incinerator without gas filters or dust control.

Although incineration reduces the volume of wastes and renders inoffensive the organic materials, the radioactive contaminants are not altered. They will pass up the flue as a gas, or, as particulate matter, will be removed with the ash, or will remain on the interior of the furnace and its stack. Stack effluents may create an atmospheric hazard in the vicinity of the incinerators. Ashes and dust become a hazard to the operator, the collector and to the public when ultimate disposal is on an open dump. Material remaining on the walls may present a radiation hazard to those working in the vicinity of the incinerator and the stack.

The AEC sponsored the incinerator study at The Johns Hopkins University in order to evaluate these hazards and insofar as possible to establish safe operating limits.

Equipment

DESCRIPTION OF THE INCINERATOR: The incinerator at The Johns Hopkins University School of Hygiene and Public Health was chosen for testing. It is a slightly modified model 2G Morse-Boulger Destructor designed to handle 200 pounds of refuse per hour. Natural gas is the auxiliary fuel. The flue, which is located in a corner of the school building, and constructed of masonry 20 inches thick, terminates in a one foot diameter steel stack 12 feet above the roof and 148 feet above the incinerator. When operated in the usual manner, ashes are removed from the incinerator in the morning and the gas fire started. Janitors and laboratory personnel dispose of combustible materials into the charging chute whenever convenient. There is no supervision of the operation.

The temperatures of the gases in the steel stack above the roof ordinarily range between 100 and 150° C. but occasionally rise to 250° C. The stack gas volume, determined with a pitot tube, ranged from 950 to 1050 cubic feet per minute.

ISOTOPE: Radioactive phosphorus, P-32, was chosen for the preliminary studies because it is one of the most frequently used radioisotopes. Radiophosphorus emits beta particles which have a maximum ener-

gy of 1.71 Mev. Its half life is 14.3 days.

SAMPLING EQUIPMENT: In the selection of sampling techniques for the stack gas and the atmosphere, it was assumed that radiophosphorus would be discharged as a particulate and, therefore, could be captured by a filter.

Two different sampling techniques were used to remove the particles from the stack gases. In one method the hot stack gases were passed through a condenser to trap the moisture prior to filtration. The gas sample was then passed through a four inch diameter filter of AEC No. 1 paper at a rate of one cubic foot per minute. This type of filter paper will remove 99.98% of the dust particles in ordinary air at a flow rate of five feet per minute.* One inch discs were removed for counting to determine the activity on the filter pad.

With this method, the small size of the sampling nozzle precluded the capture of the rather large fly ash particles discharged during the loading of trash into the incinerator and so a second sampling technique was devised. The size of the stack gas sample was increased to 30 cubic feet per minute with a proportionate increase in the size of the isokinetic sampling nozzle. The stack gas was first passed through a settling chamber to capture the large fly ash particles, and a second isokinetic sample of the discharge from the settling chamber was secured for filtration.

The sampling and counting technique was improved by building a filter cylinder into which a GM tube could be inserted to give a continuous record of activity changes. In this case, a filter rate of 0.75 cubic feet per minute was used with a total filter area of 20 square inches.

An AEC high volume filter unit was used to take atmospheric samples on the roof and in the incinerator room. The sampler is capable of sampling 20-30 cubic feet of air per minute through a 3½ inch diameter filter pad. In this work, Mine Safety Appliance Comfo Respirator filter pads (BM2130) were used. In the dusty atmosphere of the incinerator room, an electrostatic precipitator also was used for securing dust samples.

*STAFFORD, EARL and SMITH, WALTER J.: Dry Fibrous Air Filter Media. *Ind. and Engr. Chem.*, 43, 8:1346-1351, 1951.

Experimental Results

PRELIMINARY TESTS: As a preliminary step in the investigations, several local institutional incinerators were monitored in an effort to gain some idea of the activity level to be expected. The tests revealed activity considerably higher than background in all incinerators monitored. Measurements were made in the cool incinerators with a 30 milligram per square centimeter glass Geiger tube which gave a background count of 40 per minute. The results were as follows:

Incinerator Location	Activity Counts per minute
Johns Hopkins Hospital	200 - 300
Sinai Hospital	80 - 150
Hampton House	90 - 125
New Hunterian Building	200 - 300
School of Hygiene	200 - 11,000
Background	40 - 50

The discovery of high activity in the incinerator at the School of Hygiene and Public Health which was not supposed to have been used for disposal of radioactive materials, was a surprise. The stack of this incinerator was monitored at the roof level to see if any of the activity was escaping in the stack gases. A Geiger tube inserted through the stack wall yielded 2100 counts per minute.

The attempt to measure counts in a stack passing hot combustion gases raised the question of Geiger tube performance at high temperatures. Since manufacturers were unable to supply any information on tube performance at elevated temperatures, a control temperature box was constructed and D50 tubes tested and calibrated. Some of these tubes gave very consistent counts up to about 200° C. at which temperature breakdown occurred and counts climbed precipitously. However, on return to lower temperatures, performance again became normal unless the tube had suffered physical damage. Many tubes used in the stack were destroyed by intense heat flashes that occurred occasionally. Blistering of the black tube coating was the most common cause of failures. Stack counting at high temperatures was later abandoned when it was discovered that the count obtained was due almost entirely to radiation from the walls and could therefore be measured

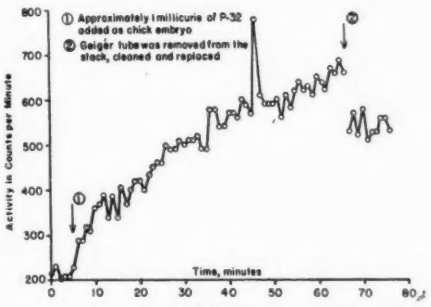
① Approximately 1 millicurie of P-32 added as chick embryo
② Geiger tube was removed from the stack, cleaned and replaced
Activity in Counts per Minute
Time, minutes

Fig. 1.
Radioactivity of incinerator stack. The Johns Hopkins University, School of Hygiene and Public Health. May 8, 1951.

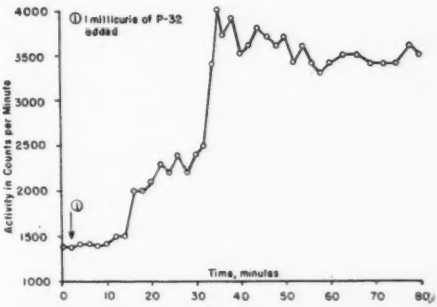

Fig. 2.
Radioactivity of incinerator stack. The Johns Hopkins University, School of Hygiene and Public Health. July 9, 1951.

in the morning before the incinerator was fired without affecting the accuracy significantly.

After calibration of the GM tube the stack was monitored for several weeks in order to follow changes in the radioactivity. During the first 10 days the decrease in counts indicated a material with an apparent half-life of eight days and during the second 10 days with an apparent half-life of 16 days. Meanwhile, an investigation of the waste disposal procedures showed that chick embryos and eggs which had been inoculated with radiophosphorus were being disposed of in the trash which went to the incinerator. This practice was discontinued and the incinerator allowed to cool off radioactively before starting a controlled series of tests.

CONTROLLED EXPERIMENTS WITH RADIOPHOSPHORUS: The first series of controlled experiments was aimed at determining the amount of radioactive material that escaped through the stack. Radioactive phosphorus in amounts ranging from 100 to 2000 microcuries was added either in the form of chick embryos or of cotton wetted with a phosphorus solution. The discharge of activity did not follow a fixed pattern, perhaps because of erratic trash charging practices and other variables connected with the type and rate of combustion. The stack discharge was usually complete within an hour after the incinerator had been charged with radiophosphorus. The tests gave a fairly good picture of the ultimate fate of that portion of the activity which came into the stack and was retained on the stack walls or could be captured by settling and filtration. With one exception the stack discharge ranged up to about 8% of the activity added to the incinerator. Some three-quarters of this was usually found on the stack wall and less than one-quarter was carried in the gas in a form that could be removed by filtration.

ACTIVITY ON STACK WALL: As a first step in determining the relative amount and nature of the radioactivity discharge in the stack gas, a charge of radiophosphorus was placed in the furnace, and the activity changes in the stack were determined with a Geiger tube. The first loading of 450 microcuries of P-32 resulted in an increase of about 100 CPM in the stack during the first hour. A subsequent charge of one millicurie increased the stack activity by 350 CPM within one hour, and another charge of one millicurie increased the activity in the stack by 2000 CPM.

No real pattern of activity discharge was apparent. With equal charges of one millicurie, in the first case, there was a slow increase in activity for a period of at least one hour, and, in the second case, there was a rapid and much larger increase in activity within 30 minutes. Figs. 1 and 2 show graphically the change in activity within the stack immediately following the addition of radiophosphorus charge.

Subsequent investigations indicated that the activity measured by a Geiger tube inserted in the stack resulted from deposits on the wall of the stack and not from activity suspended in the flue gas. Ac-

tivity determinations in the early morning, while the incinerator was not operating and still relatively cold, indicated that the activity persisted for a period of several months following the addition of radiophosphorus to the incinerator. The activity decreased approximately in accordance with the half-life of P-32 during this period.

A plot of data showing the activity of the stack wall from March, 1951, to February, 1952, is shown in Figs. 3 and 4.

The percentages of the active charge which were deposited on the stack wall rose to 6.7% as the loading increased to 1500 microcuries. The calculated retention on the stack wall for the 2000 microcurie loading was 32.3%, a value that appears unreasonably high. The data showing the amount of activity precipitated upon the stack wall in each test are shown in Tables I and II.

A review of the four methods of getting at the amount of activity in the 148 foot stack may be of interest and will give some idea of the reliability, or the lack of it, connected with these measurements.

1. Direct counting in the stack by insertion of the D50 tube through a hole bored through the metal portion of the stack about five feet above the roof level. The geometry for this method was determined by building a mock stack one foot in diameter by three feet tall and integrating the count received from a measured amount of radiophosphorus placed on a one cm. band which was slid to consecutive positions down the model.

2. Counting the radioactivity on a disc which was removed from the stack wall. The holder and tube arrangement used in the laboratory were calibrated over alumi-

TABLE I.
ACTIVITY DEPOSITED ON STACK WALL

Activity Incinerated Microcuries	Activity Precipitated on the Stack Wall[1]	
	Microcuries	Per cent
450	2.6	0.6
500	3.2	0.6
1000	4.5	0.5
1000	27.7	2.8
2000	645.	32.3
99	2.2	2.5
1501	100.	6.7
135	5.2	3.9

[1]Based on uniform wall deposit equal to concentration at discharge end of stack.

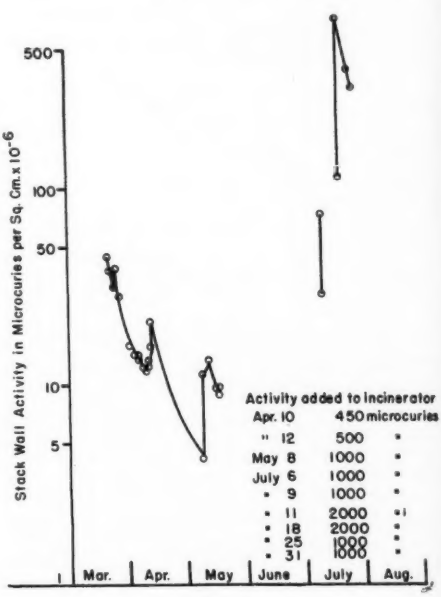

Fig. 3.
Radioactivity of stack wall with incineration P-32, 1951.

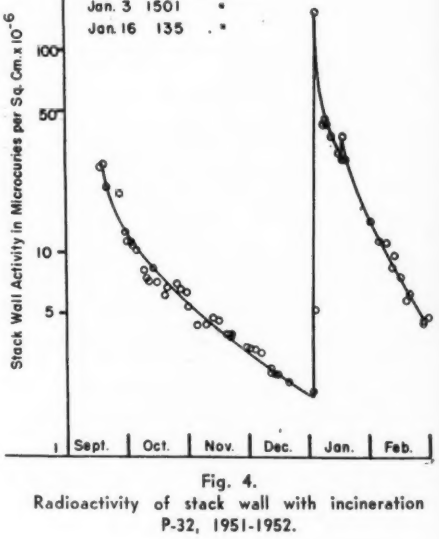

Fig. 4.
Radioactivity of stack wall with incineration P-32, 1951-1952.

TABLE II.
DISTRIBUTION OF RADIOACTIVE PHOSPHORUS ON INCINERATION

Activity Incinerated Microcuries	Activity Removed[1]		Total Activity in Stack Gas[1] Microcuries	Total Activity Precipitated on the Stack Wall[2] Microcuries	Total Activity Recovered in the Ash Microcuries
	Settling Box Microcuries per CC	Filter Microcuries per CC			
99	6.8×10^{-10}	2.6×10^{-9}	0.6	2.2	132
501	2.4×10^{-8}	1.7×10^{-5}	9.1	100.	295
1000	0.6×10^{-8}	2.3×10^{-8}	10.2		
135	4.8×10^{-10}	1.7×10^{-10}	0.5	5.2	137

[1]Based on maximum 6 min. activity discharged except for 1000 microcurie loading which was based on maximum 12 min.
[2]Based on uniform wall deposits equal to concentration at discharge end of stack.

num sheets on which had been distributed known amounts of activity.

3. Measurement of the activity in soot scraped from the stack wall. A few milligrams of soot were spread as evenly as possible on the bottom of a standard planchet and counted in a laboratory pig.

4. Measurement of activity in soot scraped from the disc removed from the stack wall.

Each of these counting methods gave a value in microcuries per square centimeter. The total activity on the interior surface of the stack was obtained by multiplying the unit area values by the estimated total surface area. The assumption of uniform distribution of activity throughout the 148 foot length of the stack hasn't been checked because of the difficulties in breaking through the 20 inch stack wall below the roof.

Results obtained by the four methods of test were, in one case, as follows:

Direct counting in the stack: 97 microcuries or 6.1% recovery

Counting of disc removed from stack: 82 microcuries or 5% recovery

Counting soot scraped from wall: 53 microcuries or 3.3% recovery

Counting soot scraped from disc: 14 microcuries or 1% recovery.

ACTIVITY IN THE GAS: The radioactivity discharged in the stack gas was determined by settling and filtering an isokinetic sample of the stack gas. A thimble filter with an integral Geiger tube was calibrated so that instantaneous values of activity discharge could be determined from the activity count. A typical activity discharge curve is shown in Fig. 5. All of the filterable radioactivity in the stack gas passed out immediately following the addition of the radiophosphorus.

The percentages of the active charge removed from the gas by settling and filtration ranged from 0.4% with a 135 microcurie loading to 1.8% with a 500 microcurie loading. The peak rate of discharge during the latter test was 5×10^{-8} microcuries per cubic centimeter of stack gas. Most of the activity recovered from the gas appeared on the filter, ranging from 64% to 82% of the total. The balance was found in the dust and flyash collected in the settling box.

Test data showing both the concentration of radioactivity in the stack gas and the total quantity recovered are included in Table II. The relatively small part of the activity ordinarily found in the gas

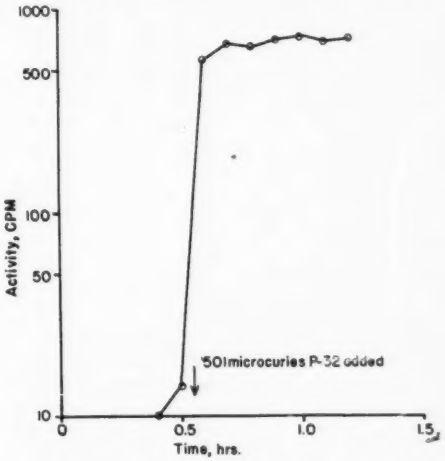

Fig. 5.
Activity of stack gas following incineration of 501 microcuries of radiophosphorus. Activity removed by filter 1 CPM—8.5 x 10-4 microcuries per cubic foot of stack gas.

and on the stack wall indicated that most of the radiophosphorus remained in the ash. This had been expected.

ACTIVITY IN THE ASH: The ash was sampled after removing the entire contents of the incinerator, some 35 pounds of material, to a drum where it could be sampled. Only about 10 milligrams could be counted at one time. The difficulty in mixing due to range in particle size and activity and the limitation on the size of sample that could be used imparted a wide variability to the results. The proportion of activity accounted for in the ash, as shown in Table II, ranged from 20% to over 100% of the charge. High calculated recoveries resulted no doubt from poor mixing. Plans are now being made to attempt to dissolve the phosphorus and count a dried sample of the liquid. It is hoped that by this means the mixing problem will be solved. The activity in the ash ranged up to 1.5×10^{-2} microcuries per gram which was measured after 1500 microcuries had been placed in the incinerator. It is a level that might produce a hazard if concentration of dust reached 30 milligrams per cubic foot of air.

TABLE III.
SYNOPSIS OF RADIOACTIVITY IN THE INCINERATOR ASH

Date		Activity in Ash: Microcuries per Gram x 10^{-4}	Activity in Ash: Microcuries
Sept.	17	177	321
	28	2.3	4
Oct.	4	3.3	6
	11	54.3	98
	12	11.5	21
	18	3.1	6
	19	2.4	4
	24	8.5	15
	25	4.6	8
	26	15.4	28
	29	3.3	6
	30	1.5	3
Nov.	2	3.2	6
	5	3.0	5
	6	0.0	0
	9	0.0	0
	12	7.9	14
	14	1.0	2
	16	3.7	7
	20	3.9	7
Jan.	3	83.2	132
	4	155	295
	7	0.5	1
	8	2.9	5
	9	23.3	42
	11	4.8	9
	15	1.3	2
	16	9.0	16
	17	65.8	137

TABLE IV.
RECOVERY OF P-32 IN MICROCURIES PER CUBIC CENTIMETER OF AIR TAKEN IN THE INCINERATOR ROOM DURING ASH REMOVAL THE DAY FOLLOWING EXPERIMENTAL INCINERATION OF P-32

Date		P-32 Incinerated Microcuries	Equipment Used[1]	Total Volume of Samples Cu. Ft.	Recovery of P-32 Microcuries per CC Air
May	8	1000			
	9		E.S.	9	0.4×10^{-3}
July	9	1000			
	10		E.S.	15	2.7×10^{-3}
	18	2000			
	19		E.S.	9	4.8×10^{-3}
			H.V.F.	105	5.3×10^{-4}
	25	1000			
	26		E.S.	6	4.0×10^{-3}
			H.V.F.	90	3.4×10^{-4}
Jan.	2	99			
	3		H.V.F.	180	0.77×10^{-3}
	3	1501			
	4		E.S.	12	2.98×10^{-3}
			H.V.F.	100	0.58×10^{-3}
	16	135			
	17		E.S.	9	1.62×10^{-3}
			H.V.F.	90	0.44×10^{-3}

[1]E.S. = Electrostatic Sampler
H.V.F. = High Volume Filter

The variation of the radioactivity of the ash is shown in Table III. Radiophosphorus had been added to the incinerator on January 2, 3, and 16, in quantities of 99, 1501, and 135 microcuries respectively. Contamination from an unknown source had obviously been placed in the incinerator on September 17 and October 10, as shown by the high activity in the ash. Data taken on the other dates suggested that only small amounts of radioactive material were being disposed of by incineration.

DUST HAZARD: Atmospheric samples were taken at breathing level during ash removal. Both the high volume sampler and the electrostatic filter were used to collect the dust. As shown in the data of Table IV, the activity ordinarily ranged from 4×10^{-10} to 5×10^{-8} microcuries per cc with loadings from 100 to 2000 microcuries.

In accordance with the "Standard Safety Requirements" of the AEC, the tolerance level for the more hazardous and common beta-gamma radioisotopes (such as iodine, strontium, barium, etc.) is considered to be 10^{-7} microcuries per cubic centimeter of air. The U.S. Sub-Committee on Internal Dose of the U.S. Radiation Protection Committee has set values of maximum permissible concentrations of general radio-

active contaminants beyond areas under the control of institutions as 10^{-9} microcuries per cubic centimeter for beta-gamma emitters. The Chalk River Conference of 1949 recommended as a maximum tolerance level 2×10^{-8} microcuries per cubic centimeter of air for contamination by P-32, 10^{-9} microcuries per cubic centimeter of air for contamination by I-131, and 10^{-10} microcuries per cubic centimeter of air for contamination by Sr-90 + Y-90.

Judged by the above information the activity concentrations in the vicinity of the incinerator during ash removal approached the danger level for continuous exposure. Since the operator ordinarily spends less than five minutes removing ashes it is not believed that he has been subjected to any hazard. However, the air tests were made at times when laboratory personnel were removing the ashes with considerable care. The dust hazard during unsupervized cleaning may be considerably greater. Furthermore, the dust hazard at this particular incinerator may be less than is ordinarily the case because strong updrafts in the warm 148 foot flue pull much of the dust away from the operator during the cleaning operation.

Work with this incinerator indicates that the dust hazard could become severe if uncontrolled disposal of radioactive waste were permitted. The rapidly increasing rate of use and the widespread dissemination of radioisotopes make the problem especially acute.

PHOSPHORUS IN VOLATILE FORM: Although most tests indicated that a major part of the P-32 remained in the incinerator, an occasional abnormal variation led to a search for ways that phosphorus might be volatilized to pass up the stack as a gas. Laboratory tests indicated that large amounts of radiophosphorus were lost when concentrated phosphoric acid was dried and heated in a muffle furnace. To check these results, labeled concentrated phosphoric acid in a planchet was placed on hot coals in the incinerator during its operation. Of the 245 microcuries placed in the incinerator, 167 were lost and presumed to have passed up the stack. A recovery of 116 microcuries was calculated from the stack gas filter test and 14 microcuries for the stack wall deposits test. This left only 27 microcuries unaccounted for, a very good check for the kind of testing involved. It is fairly evident, therefore, that if the phosphorus is in the acid form a considerable part of it may be discharged from an incinerator with the stack gases.

Summary

THE STUDY of behavior of institutional incinerators when used to dispose of radioactive wastes has so far been confined to monitoring of existing incinerators and studying the facts of radiophosphorus in wastes burned in the incinerator at The Johns Hopkins University School of Hygiene and Public Health. The findings are as follows:

1. All the incinerators monitored contained sufficient activity to suggest that radioisotopes may have been placed in them. In all cases there had been no previous monitoring of the incinerator.

2. Institutional incinerators are operated in a very erratic manner with almost no control over when, with what, and by whom they are charged. Irregular loading and combustion result in heat flashes and periods of intense burning which cause a good deal of partially burned material to be blown up the stack. The writing on some of the paper coming out the stack remains legible.

3. When charged with materials contaminated with less than two millicuries of P-32, a relatively small part of the radioisotope appears to reach the flue. Most of that which does is deposited on or with the soot which accumulates on the interior of the stack. The balance is in material that can be filtered from the stack gas.

4. The major part of the P-32 added to incinerators may be expected to remain in the ashes where it could cause a dust hazard to men who remove the ashes unless disposal practices and incinerator operation are under careful control.

Since each radioisotope presents a somewhat different problem insofar as disposal by incineration or other means is concerned, the results of tests with radiophosphorus cannot be used to evaluate hazards which may result from disposal by incineration of other isotopes. Radio-iodine will be studied next as a continuation of the proposed program.

THE GREATER DETROIT-WINDSOR AIR POLLUTION STUDY

PART I — Industry's Part

J. C. RADCLIFFE, Ford Motor Company, Dearborn, Michigan

IN AUGUST of 1950 an invitation was extended to industry in the Detroit-Windsor area to attend a meeting to discuss the proposed air pollution study in that area. This meeting which was held in September was attended by approximately 50 representatives of industry and technical personnel from official agencies.

At that time the respective chairmen of the Technical Advisory Boards of both Canada and the United States discussed the reasons behind the Detroit-Windsor Air Pollution Study.

In essence, they requested of industry, cooperation in two major fields. The first entailed the presentation of information relative to the fuel burned at each plant. These questions, on a questionnaire form, asked:

1. Name and location of plant.
2. Kinds of fuel burned (coal, coke, oil, gas, garbage, trash and other).
3. Amount burned in 1949.
4. Type of fuel burning equipment (hand-fired, underfeed stoker, spreader stoker, pulverized fuel, traveling grates, etc.).
5. Number and height of stacks.

Following this section of the questionnaire was one question requesting information regarding any auxiliary equipment, methods or operating procedures used to reduce smoke or fly ash emission, smoke indicators in use and the like. The questionnaire was further expanded to include the analysis of the fuels used. This section requested information regarding the size, volatile, ash and sulphur, in percent by weight on a dry basis, for coal or coke used. For oil, the percent by weight of sulphur, and for gas, the percent by volume of sulphur was requested.

Obviously, the data supplied by these questionnaires should give a fairly representative picture of the combustion processes in the area with a general idea of the degree of control now in effect. In addition, it should pin-point a large portion of the potential sulphur sources, and thus the SO_2 problem.

THE SECOND major field which at this time the technical advisers discussed was one which could become never-ending. The request as posed on the questionnaire was, "Companies operating plants which emit gases and solids into the atmosphere, other than ordinary products of combustion and fly ash, are to supply the following information:

1. Type of process.
2. List raw material used.
3. List finished products and approximate annual output.
4. Nature of effluents.
5. Height at which discharged.
6. Methods adopted for reducing amount of this effluent."

THERE THEN followed on the questionnaire a section for further remarks. I am quite sure that this section of the questionnaire was not 100% completed by many industries. If industry had the answers to all of this second set of questions they would be in an extremely enviable position. As it is, many industries have a long way to go in this direction.

This last series of questions brought up the obvious lack of final data on the vari-

ous processes in use in the area; and a discussion was held relative to the best methods of obtaining such results. It was indicated that the official agencies would be able to do some stack sampling work along with their area type sampling. However, it was further indicated that they desired industry's cooperation where possible in this representative stack sampling program. Thus, a separate technical coordinating committee was established with official agency and industrial representative for the *express purpose of establishing standard techniques and cooperative methods of sampling* so that results obtained by all parties concerned would be consistent at least as far as method was concerned.

IN THE ESTABLISHMENT of uniform methods for sampling stacks to be used by participating groups in the air pollution study of the Detroit-Windsor area, it should be realized that insufficient knowledge is available to establish hard and fast rules, and considerable discretion must be employed by the investigator.

Various standard methods proposed by the A.S.M.E. and other groups were reviewed and finally the following general rules were adopted.

Particulate matter should be evaluated in terms of grains per cubic foot and milligrams per cubic foot, calculated to 760 mm of mercury pressure and 77°F or 25°C.

Particle size shall be expressed in terms of microns (1 micron equals 0.001 mm) but above 44 microns may be expressed in terms of sieve size. Qualitative information should be given concerning the surface-density ratios of particles e.g. needle, plate and sponge-like particles should be so designated. As a rough guide, if the settling rate of the particle as calculated by Stokes' Law exceeds the predicted by 50%, this fact should be mentioned.

Ideally, sampling openings should be located in the vertical stack at a point at least 10 diameters from the last bend or transition and at least one diameter before the next bend or transition, if a single center line sampling point is to be used. This is usually not feasible in large stacks and frequently the point must be located in the breeching. If the sample point must be located in a rectangular stack or breeching of unusual width in respect to thickness, or less than three diameters ahead of the last bend or transition, or one diameter before the next bend or transition, then the sampling point must be a representative traverse of the stack. A preliminary study of velocity variations should be made in every situation before locating the sample point, but one center line point is usually satisfactory at locations more than three diameters from the last bend of transition.

Temperature of the stack gases can most conveniently be measured with a thermocouple type of pyrometer, or in cool stacks of small diameter with a thermometer.

Velocity measurements should be made on all stacks in order to properly determine the location and number of sampling points required. Pitot tubes or impact tubes with inclined manometers may be used to measure gas flows above 700 LFM, but the accuracy is poor below 1000 LFM. Portable hot wire anemometers may be used above 50 LFM at temperatures below 400°F. Vane type velometers may be used for velocities above 100 LFM for temperatures below 500°F. (Reading time in hot gases should be kept short and filter should be used if gases are dirty or instrument may be damaged.)

Metallic sample probes for use up to 800°F. should be constructed of stainless steel. Sampling tubes shall not be less than ¼" I.D. Tubes above ½" I.D. are inconvenient to use in thick-walled stacks unless large sampling ports are provided.

Glass sampling tubes of pyrex or vycor type glass are desirable for corrosive gases, mists and sticky materials.

The inlet device should form a 90° angle with the sampling probe and be connected with a smooth bend. It frequently is inconvenient to have the inlet device project more than two to four inches below the sample probe. The inlet device shall be threaded to permit the fitting of intake nozzles of different inside diameters. The bore must be uniform and the outside diameter should be tapered to form a sharp edge at the intake circumference. Null type sampling heads may be used but they are inconveniently large.

Particulate Matter: A standard impinger operating at one cfm or above should be

used for the primary collector. If the dust particles are so large as to cause troublesome plugging, a preliminary trap should be provided. A secondary collector may follow the impinger for special study work on fine particles. The collecting liquid should be ethanol, iso-propanol or n-butanol.

Gases: Gas concentrations above 0.5% by volume should be determined by gas volumetric analysis.

Gas concentrations below 0.5% by volume should be collected with a fritted glass or petticoat type bubbler using an appropriate solvent. The efficiency of other washing devices must be established before use.

Flow rates should be determined with a rotometer or orifice type meter equipped with a U-tube or differential diaphragm gauge. All orifice meters must be calibrated under anticipated operating conditions against a standard meter. Such are available at the Gas Company, the Michigan and Detroit Health Departments, Bureaus of Industrial Hygiene.

A Wilson pump apparatus or a Lieman Brothers Pump powered with an appropriately sized induction type motor have been found satisfactory for one cfm airflows. Any rugged pumping system capable of handling the desired gas volume is satisfactory.

Examination of Atmospheric Samples

Coarse dust in which approximately 70% by weight of the particles are above 44 microns, e.g. boiler or cupola stacks, should be sampled with a large capacity collector and at least 100 gms. of sample obtained. Size according to ASTM procedure using a 325 mesh sieve for the smallest screen size.

Impinger samples should be used for all particle size determinations when the particles to be sized are between one and 44 microns. The particles may be sized into three groups (1-10; 11-20; 21-44 microns) for convenience and simplification. Particles may be so sized by the following procedure:

1. Obtain about 200 mg of material.
2. Suspend in alcohol.
3. Add sample to tall form beaker provided with mark two cm from bottom and eight cm from bottom, dilute to upper mark and mix.
4. Using Stokes' Law, compute settling time for given range.
5. Completely mix sample, let settle for the calculated time, siphon liquid off to lower mark, spin down the siphon liquid in a centrifuge or filter through a filtering crucible. Re-dilute sample in beaker to upper mark and repeat procedure three to 20 times, depending upon nature of dust and accuracy desired. Three to five times are usually enough for any size range.
6. Check particle size distribution in a given range by transferring portion to a dust counting cell, let settle about 20 to 30 minutes, and examine with an optical microscope fitted with a 10X objective and a filar micrometer eyepiece or microprojector.
7. If dust is separated by filtration, dry at temperature of 100 to 105°C. If separated by centrifuge, transfer to weighing dish and evaporate to dryness on a hot plate with a surface temperature not exceeding 110°C or on a water bath. For sizing in the 0-1 micron range, an electron microscope or other appropriate device must be used.

Discharge from Boiler Stacks

1. Determine loss on ignition (separate sample).
2. Total weight of solid discharge.
3. Particle size.
4. Orsat analysis for CO_2, O_2, and CO, special analysis for SO_2, SO_3, and NO_2.
   (a) Gas samples should be taken over entire observation period, at least 10 being taken.
5. For power houses with multiple stacks, sample at least two equivalent stacks.
6. If information concerning metal content of solid discharge is desired, make analyses on 0-10 micron size fraction.

Discharge from Iron Foundry Cupolas

1. Determine loss on ignition.
2. Determine total weight of discharge.
3. Determine particle size.
4. Orsat analysis for CO_2, O_2, and CO, special analysis for SO_2, SO_3, and NO_2.
   (a) Gas samples should be taken over entire observation period, at least 10 being taken.
5. Determine iron oxide—treat as iron ore sample.

6. Optional determination of other metals such as Mn, Te, etc.

Discharge from Brass Foundry Cupolas

1. Determine total solids.
2. Determine particle size.
3. Obtain filter paper samples for Pb, Zn, and Cu determinations.

Discharge from Sintering Plants

1. Determine total solids.
2. Determine particle size.
3. Determine iron content.
4. Determine carbon monoxide.

Other Metallurgical Stacks

1. Open hearth, automatic scarfing, arc furnaces.

(a) Determine total solids, iron oxide, particle size and NO_2.

Smelting and Refining

1. Total solids and particle size.
2. Pb, Zn, Cu, Al, Cl_2, HCl, Cd, As, Sb, arsine, stibine, Be, U, fluorides, chlorides, SO_2, and others as required.
3. Solids collection should be made on filter paper.

Coke Ovens

1. Determine H_2S, NH_3, and mercaptans.

Incinerator Plants

1. Determine total solids.
2. Determine loss on ignition.
3. Determine particle size.
4. Determine carbon monoxide.

Cement Plants

1. Determine total solids.
2. Determine particle size.
3. Determine H_2S and SO_2.

Steel Pickling

1. Determine H_2SO_4, NO_2 and HF.

Miscellaneous

Miscellaneous chemical and process industries such as chemical, plating, heat treating, wood working, paint and varnish, plastic, painting and protective coatings, etc., provide many special problems which can usually be solved by the usual sampling methods but will require special analytical consideration. Methods in "Industrial Poisons, Hazards and Solvents" by Jacobs are especially applicable.

AFTER THE committee action on general standard methods of analyses were formulated, a training course was established to instruct those who would be analyzing the effluents from the various stacks in the area. The course was set up with the University of Michigan Extension Service as a non-credit course and was given in a centralized Detroit location one afternoon a week for two hours each day over an 18 week period starting in September of 1951. Lectures were given by various authorities on the individual subjects covered. These subjects included the following:

1. General Aspects of Air Pollution.
2. Toxicology of Air Contaminants.
3. Fuel Combustion.
4. Principles of Industrial Stack Sampling.
5. Principles of Flow Measurement.
6. Principles of Air Sampling.
7. Methods of Determining Particle Size.
8. Methods of Analyzing Particulate Matter.
9. Methods of Analyzing Gases and Vapors.
10. Control Equipment.
11. Interpretation of Data.

Many industrial representatives attended these courses and since have begun their respective stack evaluations. The majority of industries seem to have followed the procedure of first listing all their operations with their respective exhaust stacks. Some numerical listing of these stacks and operations is then made.

From this initial mapping or planning stage there must then develop an agreement regarding the order in which the stacks would be sampled. Normally those operations which are thought to be prime contributors from a visual viewpoint are put first and minor ones last. This initial planning also in some cases eliminates some of the stacks from further consideration due to the operation they are connected with.

In order to insure a common sampling procedure most industries plan to have similar sized holes put in the various

stacks. Then only one basic type sampling probe is required for all stacks.

Results to date are small in number due to the fact that the series of lectures detailing methods of sampling and analysis has only recently been completed. The results when obtained will have a two fold application. First, the results will indicate to the specific industry concerned, the degree of their problem, and thus the corrective action needed. Secondly, the results should be forwarded to the Technical Advisory Board. This Board desires only stack results with the notation that they are from a certain type of process. They do not want the name of the plant from which the results were obtained, because their purpose is not to condemn any specific industry, but rather to indicate the probably overall pollution problem.

The most promising aspect of this entire program from an industrial viewpoint is not primarily the correction of already existing conditions, but the designing and building of control devices into each new operation as it is developed. This type of control planned before the foundation is laid for the building is the type which will in time be of prime importance in the control of air pollution. Industry is now asking for bids from collection device companies which guarantee that the collector will emit an effluent which is well within the existing air pollution codes. In addition industry is becoming more familiar with the advantages and disadvantages of various types and makes of collecting devices.

In general, the extent of industry's participation in this program indicates their desire to be good neighbors. The cost of control of all stack emissions in the Detroit-Windsor area from industry alone is tremendous. These types of expenditures are not effected overnight. However, it is believed that in time these problems will be gradually eliminated, until industry's portion of the total air-pollution load will be only a small fraction of the total.

The Greater Detroit-Windsor area contains a population of about three million and is the third largest manufacturing region in North America. In addition, the Detroit River carries the largest vessel traffic in the world during the navigation season. Domestic and industrial consumption of coal and other solid fuels amounts to about 16 million tons annually and it is estimated that about 430 thousand tons or more of sulfur dioxide are released to the air during combustion. To this pollution must be added large quantities of gaseous and aerosol contaminants of varied character.

The rise and fall of the level of sulphur dioxide in the air has been chosen as an index of gaseous pollution since this gas is one of the major contaminants in quantity in the area. At the station showing the heaviest sulphur dioxide pollution, the highest monthly mean concentration was 0.149 ppm in December 1951, with a 10-minute peak of 1.210 ppm. The lowest monthly mean at this station was 0.047 ppm in June 1951. Other objectionable gaseous contaminants which have been found in significant amounts at various sampling stations are hydrogen sulfide, chlorine, oxides of nitrogen and ammonia.

The rise and fall in the daily mean concentration of suspended particulate matter has usually been correlated with parallel fluctuations in the daily average of sulfur dioxide. The mean concentrations of particulate matter from continuous filtration samples vary from about 0.200 to 0.238 milligrams per cubic meter with maxima ranging from 0.450 to 0.556 mg./cu.m. in the more heavily polluted areas of Windsor. The means for the areas of low pollution vary from 0.086 to 0.073.

The complexity of the suspended and deposited dust is illustrated by the results of chemical and spectrographic analyses.

All these studies of the environment are being correlated with a view to providing enough information to serve as a basis for surveys of the effects of such conditions on public health, vegetation, safety and economy.

PART II — Investigation of Environmental Contaminants by Continuous Observations and Area Sampling

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Chairman, Canadian Section, Technical Advisory Board of Air Pollution, International Joint Commission

THIS PAPER will indicate the scope of the Canadian contribution to the air pollution study of the Detroit-Windsor area and give in some detail the nature, distribution, and composition of gaseous and aerosol contaminants as well as the influence of meteorological factors on their dissemination and diffusion.

For the purpose of this environmental study, the centres of population and industry on both sides of the international boundary of the Detroit River may be considered as one area. The estimated population on the U.S. side for the entire metropolitan area was about 2,775,000, in 1949, of which 2,365,000 represented the population of Wayne County. The population of Greater Windsor is about 160,000. This region of about three million inhabitants is one of North America's greatest concentrations of industry. There are more than 4000 industrial establishments in Wayne County alone and Detroit is the third largest manufacturing centre in the U.S. Although the automotive industry occupies a dominant position in both Detroit and Windsor, there are large establishments which produce steel and pig iron, heavy chemicals, paints and varnishes, pharmaceuticals, electrical appliances, stoves and furnaces, brass and iron foundry products, machine and cutting tools, soda ash, synthetic resins and plastics, solvents and organic chemicals, rubber products and adhesives, caustic soda and chlorine gas, phosphate and phosphoric acid, pulp and paper, and refined petroleum products. In addition, the Detroit River is the scene of the largest vessel traffic in the world during the navigation season. The vessel fleets of the Great Lakes may execute over 28,000 passages of the Detroit River in transporting over 100 million tons of cargo in a given season.

It is estimated that the total domestic and industrial consumption of coal and solid fuels in this area consists of about 15 million tons on the U.S. side and about 650,000 tons on the Canadian side of the International Boundary. In addition, there is the coal consumed by vessel traffic on the Detroit River. A conservative estimate yields a total of at least 16 million tons. The average sulphur content of this fuel is at least 1.5% and about 90% of this sulphur is released to the atmosphere during combustion. On this basis, approximately 430,000 tons of sulphur dioxide are emitted to the air annually from solid fuels alone. This total is further augmented by the sulphur oxidation products from the combustion of natural gas, fuel oil, gasoline, and from other sources such as metallurgical, chemical and paper mill operations.

In addition to this large amount of pollution by sulphur dioxide, there are many process wastes consisting of gases and aerosols which contaminate the atmosphere. These may be listed more definitely as follows:

(1) Soot, smoke, fly ash, and dusts from mechanical and chemical operations.

(2) Organic matter and tar fog from combustion operations. Gaseous hydrocarbons, carbon monoxide, organic aldehydes, peroxides and acids from internal combustion engines and other operations.

(3) Sulphur compounds including sulphur trioxide, sulphuric acid and hydrogen sulphide.

(4) Fluorine and chlorine compounds,

Presented as D.R.C.L. Report No. 93 before the joint meeting of the American Conference of Government Industrial Hygienists and the American Industrial Hygiene Association, April 22, 1952.

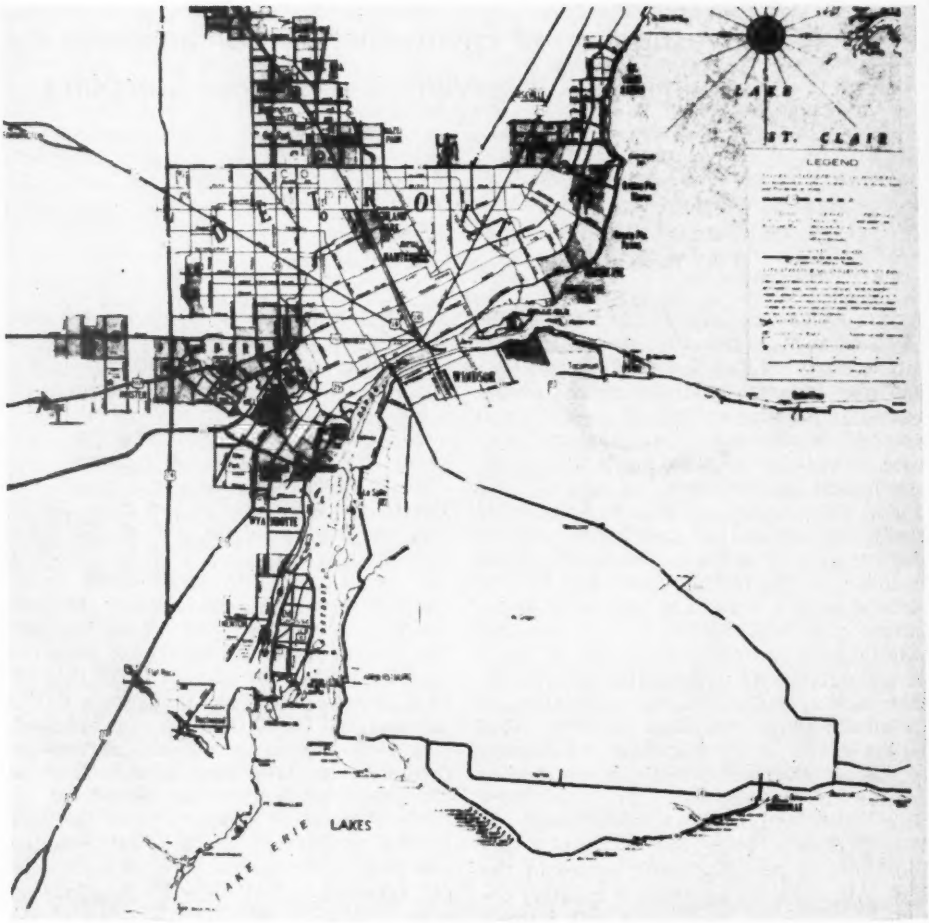

Fig. 1.
Map of the Greater Detroit-Windsor Area.

oxides of nitrogen, nitric acid and ammonia.

(5) Metallic fumes and oxides from foundry, steel mill and other metallurgical operations.

The environmental studies in this area have been designed to determine the maxima, minima, and average pollution as influenced by meteorological and other factors over a sufficiently long period so that the resultant effects on public health, economy, safety and vegetation may be properly evaluated. Obviously, such a study demands the application of techniques involving continuous observations and sampling on an area basis. It has been demonstrated by Katz,[9,10] Thomas,[22] and others,[3,4,8] that no adequate knowledge of the diurnal variation, and of weekly, monthly, and yearly cycles of pollution can be obtained by other than continuous sampling technique. A comprehensive picture of pollution in the environment is difficult, if not impossible, to achieve by intermittent sampling methods. Meteorological factors, which cause great variations in pollution, are operative throughout the 24-hour day and also fluc-

tuate with the seasons of the year. Environmental evaluations must, of necessity, be approached on this basis. Sufficient apparatus and equipment must also be employed to delineate the areas of high and low pollution if a successful attack is to be made on problems such as the chronic effects of air pollution on community health and public welfare, including the effects on vegetation.

Although the investigation on the Canadian side of the international Detroit River Area was organized in the summer of 1949, about one year earlier than that on the U.S. side, a standardized approach was adopted by the Technical Advisory Board for both sides. One of the foremost problems in this area was the excessive emission of smoke from vessels plying the Detroit River. The Canadian side, since 1949, has been responsible for the collection and reporting of data on smoke emission from vessels for both Canada and the United States. Thousands of readings have been made by observers, using the Ringelmann Chart method, in each navigation season. There has been a marked improvement in smoke performance within the past year as a result of efforts made by the Dominion Marine Association and Lake Carriers' Association under their Great Lakes Air Pollution Abatement Program, organized in the summer of 1950. The percentage of the time of smoke observations from vessels corresponding to No. 3 Ringelmann and darker, which in 1950 amounted to about 51%, was reduced to about 35% in 1951. The establishment of improved fuel specifications, the development of approved steam-air jet installations for stoker-fired water tube boilers, the initiation of an educational program and research on combustion aids for hand-fired Scotch marine boilers will, it is hoped, still further reduce excessive smoke from vessels in 1952. The Technical Advisory Board has set objectives which limit smoke emission from vessels and has requested that vessels in various equipment categories comply with these objectives. Smoke performance data will be collected and owners will be notified if vessels fail to meet the standards set.

Weather Conditions

THE AREA involved in this study embraces the Detroit River from Peach Island on the north to Grosse Isle on the south, and extending fifteen miles inland on either side of the river. This area includes on the U.S. sides the municipalities of Metropolitan Detroit, Dearborn, River Rouge, Wyandotte and Trenton. On the Canadian side are the municipalities of Tecumseh, Riverside, Windsor, LaSalle and Amherstburg. The terrain is predominantly flat but the climate and wind pattern are undoubtedly influenced by the presence of Lakes Huron and St. Clair to the north and Lake Erie to the south. The map in Fig. 1 indicates the boundaries of the area described.

TABLE I.
SUMMARY OF METEOROLOGICAL DATA, DETROIT-WINDSOR AREA

	U.S. Weather Bureau, Detroit				Windsor Airport	
	Mean Wind Direction, Percent of Hours, 1945-1948				Winds, 1945-1949	
Month	Direction NE, E, SE, and S	Direction N, NW, W, and SW	Mean Hourly Speed 1945-1949	Mean Number Cloudy Days, 1945-1949	Prevailing Direction	Mean Hourly Speed
January	32	68	10.5	20	W	12.6
February	30	69	10.6	18	W	12.7
March	46	53	11.0	17	SW	12.5
April	46	53	11.1	15	SW	11.8
May	45	54	10.0	16	SW	9.7
June	46	53	8.7	15	SW	7.3
July	42	57	8.2	10	SW	6.2
August	41	57	7.3	7	SW	4.9
September	50	49	8.7	11	SW	6.9
October	38	61	8.9	11	SW	7.3
November	37	62	11.1	20	SW	9.8
December	28	71	11.4	19	SW	10.9
		Indeterminate, 1%				

TABLE II.
MONTHLY MEAN AND MAXIMUM CONCENTRATIONS CALCULATED AS SULPHUR DIOXIDE IN PPM IN THE WINDSOR AREA, SEPTEMBER 1950 TO DECEMBER 1951
(Data from continuous Thomas autometer observations at four stations)

	STATIONS							
	No. 1 Caron and Sandwich		No. 2 Peter and Chappell		No. 4 Walker Road and Mohawk		No 3. McGregor, Ontario, 15 miles south of Detroit River	
Month 1950	Mean ppm.	Max. ppm.	Mean ppm.	Max. ppm.	Mean ppm.	Max. ppm.	Mean ppm.	Max. ppm.
September	0.074	0.308	0.026	0.096	0.033	0.294	0.010	0.155
October	0.071	0.264	0.023	0.173	0.028	0.185	0.012	0.142
November	0.063	0.326	0.035	0.149	0.022	0.214	0.011	0.307
December	0.091	0.557	0.045	0.183	0.059	0.317	0.0266	0.252
1951								
January	0.073	0.250	0.020	0.108	0.0034	0.062	0.0015	0.044
February	0.088	0.285	0.034	0.221	0.0085	0.185	0.0030	0.059
March	0.076	0.207	0.038	0.225	0.0031	0.095	0.0032	0.031
April	0.107	0.413	0.049	0.288	0.0079	0.189	0.0008	0.039
May	0.122	0.363	0.038	0.335	0.0071	0.230	0.0033	0.069
June	0.047	0.228	0.014	0.083	0.0060	0.079	0.0039	0.066
July	0.070	0.387	0.062	0.496	0.0062	0.085	0.0012	0.080
August	0.088	0.234	0.033	0.407	0.0079	0.098	0.0039	0.102
September	0.093	0.275	0.037	0.259	0.0081	0.130	0.0035	0.092
October	0.119	0.465	0.047	0.193	0.021	0.234	0.0035	0.094
November	0.104	0.421	0.048	0.347	0.019	0.146	0.0050	0.105
December	0.149	0.445	0.055	0.229	0.040	0.294	0.010	0.096

A five-year summary of the prevailing winds, mean wind direction, mean hourly wind speeds, and mean number of cloudy days are shown in Table I. Although the prevailing wind direction in this area is southwest on the basis of long term statistics, there are some exceptions in individual months of the year. During the months of October, November, December, January and February, winds are considerably more frequent from the north, northwest, west and southwest directions than from opposite directions. In March, April, May and June, the winds from the former directions are only slightly higher in duration than those from the latter. In July and August, northerly, southwesterly and westerly winds again predominate to a larger extent, whereas in September, the winds in the above two groups of directions are about equally balanced in persistence.

The mean hourly wind speed decreases in the summer months from May to August and then begins to increase in the autumn to the higher values prevalent in the winter months. The number of cloudy days is lowest in August and highest in the months of November, December and January.

Environmental Contaminant Studies

SULPHUR DIOXIDE POLLUTION: Sulphur dioxide is probably the principal toxic gaseous contaminant in quantity in this area. Continuous observations have been in progress for about eighteen months on the Canadian side of the Detroit River, with Thomas autometers located at three

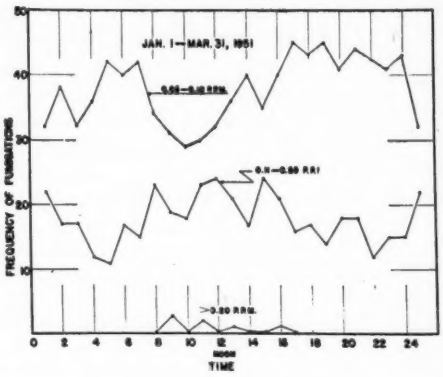

Fig. 2.
Distribution of frequency of various sulphur dioxide fumigations in hours during period January 1—March 31, 1951, at Windsor Autometer Station No. 1.

stations within the more heavily contaminated area, and at a fourth station at McGregor, Ontario, about fifteen miles south of the river. Two of these stations have been located a short distance from the Detroit River, No. 1 near the Windsor-Detroit Tunnel entrance, and No. 2, about one mile southwest of the International Bridge. The third Windsor station, No. 4, was located on the Walker Road, about one and a half miles east of the Detroit River.

In view of the high persistence of winds from the north, northwest, west and southwest directions, the sulphur dioxide observations at these stations are influenced by effluents from sources on the U.S. side of the International boundary, as well as

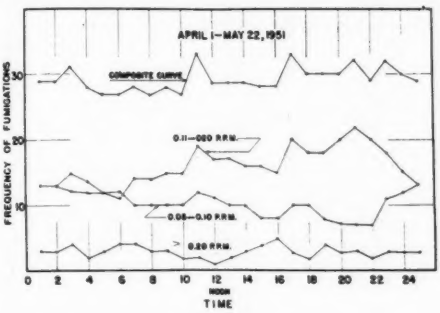

Fig. 3.
Distribution of frequency of various sulphur dioxide fumigations in hours during period April 1—May 22, 1951, at Windsor Station No. 1.

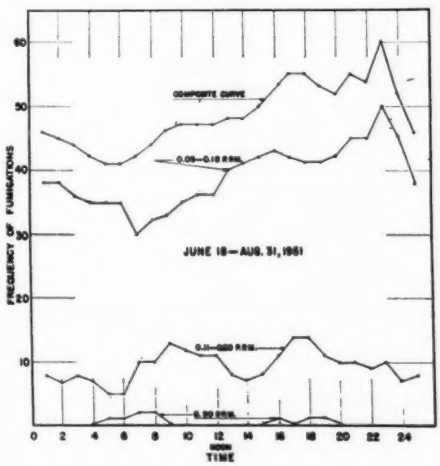

Fig. 4.
Distribution of frequency of various sulphur dioxide fumigations in hours during period June 18—August 31, 1951, at Windsor Autometer Station No. 1.

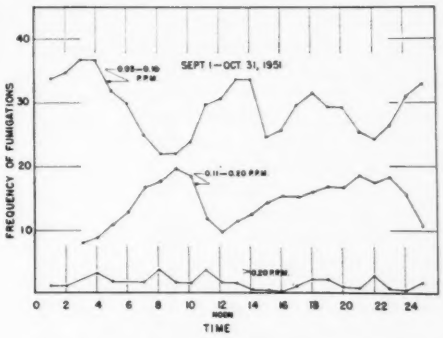

Fig. 5.
Distribution of frequency of various sulphur dioxide fumigations in hours during period September 1—October 31, 1951, at Windsor Autometer Station No. 1.

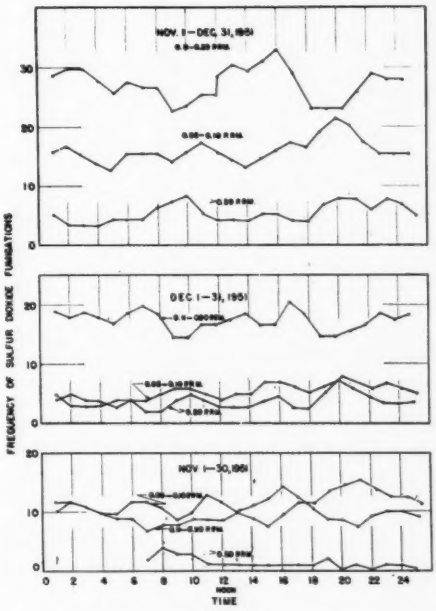

Fig. 6.
Distribution of frequency of various sulphur dioxide fumigations in hours during period November 1—December 31, 1951, at Windsor Autometer Station No. 1.

from the Canadian side. The mean concentration at each autometer station has been calculated for every thirty-minute period of the day. Peak concentrations over shorter time intervals have also been evaluated whenever such peaks have indicated unusual fluctuations in concentration. The mean values of all observations for each month of the year and the monthly maximum concentrations (30-minute maximum) are given in Table II for the period, September, 1950 to December, 1951. A comparison of the monthly means for 1951 indicates the existence of two seasonal peaks in the pollution load. These peaks occur in the spring months of April and May and in the late fall and early winter period. At Station No. 1, where the heaviest fumigations have been recorded, the monthly means varied from a low of 0.047 ppm in June to a high of 0.149 ppm in December, 1951. At the location fifteen miles south of the Detroit River (McGregor, Ontario) the highest monthly mean of 0.0266 ppm occurred during December, 1950.

TABLE III.
COMPARISON OF FREQUENCY DISTRIBUTIONS (IN PERCENT) OF THOMAS AUTOMETER OBSERVATIONS (CALCULATED AS SO_2 IN PPM) AT STATIONS IN THE GREATER WINDSOR AREA, SEPTEMBER 1, 1950 TO DECEMBER 31, 1951

	Percent time at Zero Concentration			Percent time at 0.01-0.05 ppm			Percent time at 0.06-0.10 ppm		
	Windsor Stations			Windsor Stations			Windsor Stations		
Month 1950	No. 1	Mean of 1-2-4	McGregor, Ont.	No. 1	Mean of 1-2-4	McGregor, Ont.	No. 1	Mean of 1-2-4	McGregor, Ont.
Sept.	0.0	13.4	51.3	27.2	48.1	45.4	55.3	30.3	3.3
Oct.	0.0	6.1	48.8	26.2	57.6	49.3	58.3	29.6	1.4
Nov.	2.2	9.5	57.0	47.0	60.0	36.5	42.8	26.0	5.0
Dec.	1.6	7.8	55.0	26.5	38.1	42.4	42.5	38.3	2.3
1951									
Jan.	5.1	31.2	87.0	24.5	42.5	13.0	46.5	18.4	0.0
Feb.	0.3	26.6	85.8	8.4	31.0	14.1	62.3	31.9	0.1
Mar.	0.3	33.8	85.8	28.6	31.9	14.1	47.3	25.5	0.0
Apr.	4.3	30.1	95.8	24.2	28.8	4.2	27.6	24.3	0.0
May	0.0	25.7	76.0	7.7	39.0	24.0	31.8	14.9	0.0
June	25.1	50.1	71.0	41.7	37.8	28.8	23.1	8.6	0.2
July	5.3	25.4	92.3	22.1	39.0	7.4	57.5	29.7	0.2
Aug.	0.4	25.0	81.8	8.1	40.3	17.8	69.5	27.1	0.4
Sept.	0.0	28.4	86.6	13.4	40.3	13.9	57.2	21.2	0.2
Oct.	0.2	14.4	86.9	9.9	44.7	12.4	52.1	27.2	0.5
Nov.	0.0	15.3	84.7	13.7	42.9	14.5	43.6	26.9	0.8
Dec.	0.0	15.0	69.4	5.0	30.4	29.2	16.1	23.7	1.4

	Percent time at 0.11-0.15 ppm			Percent time at 0.16-0.20 ppm			Percent time at 0.21 ppm and over		
	Windsor Stations			Windsor Stations			Windsor Stations		
1950 Month	No. 1	Mean of 1-2-4	McGregor, Ont.	No. 1	Mean of 1-2-4	McGregor, Ont.	No. 1	Mean of 1-2-4	McGregor, Ont.
Sept.	12.3	6.1	0.2	4.7	1.7	0.0	0.5	0.4	0.0
Oct.	10.3	4.9	0.4	4.1	1.4	0.0	0.1	0.1	0.0
Nov.	4.8	2.9	1.5	3.0	1.5	1.5	0.2	0.1	0.1
Dec.	17.6	10.3	0.0	8.0	4.4	0.1	3.9	1.5	0.1
1951									
Jan.	19.8	6.6	0.0	4.1	1.4	0.0	0.0	0.0	0.0
Feb.	24.3	8.6	0.0	3.7	1.5	0.0	1.0	0.4	0.0
Mar.	21.5	7.8	0.0	3.3	1.3	0.0	0.0	0.0	0.0
Apr.	17.4	7.5	0.0	21.8	7.7	0.0	4.7	1.6	0.0
May	30.8	11.0	0.0	19.0	6.8	0.0	8.5	3.2	0.0
June	7.8	2.6	0.0	1.6	0.5	0.0	0.7	0.2	0.0
July	10.1	3.8	0.0	3.3	1.4	0.0	1.1	0.5	0.0
Aug.	19.5	6.7	0.0	2.4	0.8	0.0	0.1	0.1	0.0
Sept.	20.7	7.2	0.0	7.3	2.4	0.0	1.4	0.5	0.0
Oct.	21.7	8.1	0.0	9.6	3.4	0.0	6.5	2.2	0.0
Nov.	27.8	9.9	0.0	10.6	3.6	0.0	4.3	1.4	0.0
Dec.	32.4	14.2	0.0	29.9	10.2	0.0	16.4	5.8	0.0

The pollution load, as indicated by variations in intensity and frequency of sulphur dioxide fumigations, shows marked seasonal as well as diurnal trends. These trends are illustrated graphically by the curves in Figs. 2 to 6. The figures show a plot of the frequency of fumigations in hours at various times of the day for each season of the year. In this comparison the occurrence of concentrations lower than 0.05 ppm has been neglected because such concentrations may be present in city air at all times of the day, even under conditions of optimum turbulence and diffusion. Three levels of concentration have been plotted: (1) The frequency of light fumigation between 0.05 to 0.10 ppm; (2) The frequency of medium fumigations at the 0.11 to 0.20 ppm level; (3) The frequency of heavy fumigations above 0.20 ppm.

During the period, January 1 to March

TABLE IV.

MAXIMUM CONCENTRATIONS OF SULPHUR DIOXIDE OF LESS THAN 30 MINUTES' DURATION AT THOMAS AUTOMETER STATIONS DURING SMOG VISITATIONS IN THE GREATER WINDSOR AREA

		Maximum Concentrations in ppm					
Month	Date	Station No. 1	Station No. 2	Station No. 4	McGregor, Ont. Station No. 3	Prevailing wind direction	Mean wind velocity, mph
1950							
December	19	0.710	0.336	0.576	0.138	SW	5.7
"	20	0.317	0.177	0.254	0.146	W	5.4
"	29	0.520	0.224	0.284	0.109	SW	5.4
"	30	0.776	0.191	0.468	0.102	W	2.8
1951							
February	9	0.516	0.260	0.270	0.058	NW	2.8
"	10	0.335	0.300	0.172	0.107	S	10.4
April	6	0.363	0.245	0.234	0.0	S	6.0
"	11	—	0.324	0.364	0.124	SW	8.6
"	18	0.312	0.168	0.01	0.0	S	10.5
"	20	0.390	0.181	0.074	0.110	E	4.8
"	23	0.531	0.120	0.029	0.0	SW	13.9
"	24	0.435	0.130	0.038	0.0	S	8.0
"	25	0.371	0.156	0.034	0.0	E	13.9
May	8	0.363	—	0.107	0.065	W	10.6
"	9	0.428	—	0.063	0.0	SW	13.8
"	24	—	0.288	0.230	0.042	NW	8.4
"	25	—	0.422	0.061	0.044	SW	7.8
July	4	0.469	0.195	0.034	0.101	W	13.0
"	5	0.310	0.585	0.066	0.0	N	13.8
"	6	0.254	0.414	0.109	0.026	N	3.8
"	7	0.854	0.370	0.107	0.0	SW	7.4
"	9	—	1.022	0.100	0.051	SW	9.2
"	10	0.168	0.582	0.069	0.049	SW	5.2
"	25	0.360	0.495	0.0	0.0	SW	4.5
"	26	0.347	0.657	0.045	0.0	SW	5.5
October	1	0.622	0.189	0.280	0.245	SE	2.0
"	10	0.465	0.235	0.089	0.0	NE	3.0
"	11	0.802	0.270	0.203	0.231	NW	1.5
"	12	0.553	0.255	0.256	0.081	NE	3.3
"	21	0.367	0.287	0.032	0.022	S	5.2
"	23	0.728	0.730	0.101	0.0	NE	11.0
November	5	0.335	0.230	0.196	0.094	W	6.3
"	7	0.698	0.137	0.035	0.0	SW	7.4
"	9	0.476	0.188	0.055	0.057	SW	9.2
"	10	0.414	0.282	0.083	0.052	SW	7.7
"	11	0.251	0.335	0.146	0.099	NW	1.7
"	22	0.979	0.312	0.185	0.041	SW	15.5
"	25	0.393	0.173	—	0.083	SE	5.9
"	27	0.338	0.269	0.043	0.074	N	8.8
"	30	0.319	1.105	0.237	0.072	SW	9.0
December	4	1.128	0.301	0.117	0.069	SW	9.9
"	6	0.862	0.322	0.132	0.033	S	8.9
"	7	0.381	0.374	0.075	0.067	SW	16.4
"	12	0.514	0.824	0.438	0.053	W	13.5
"	13	0.459	0.238	0.336	0.151	W	11.2
"	14	0.459	0.329	0.326	0.091	NE	12.7
"	19	0.942	0.245	0.468	0.164	NW	4.6
"	20	0.392	0.111	0.209	—	SE	9.5
"	23	0.409	0.228	0.262	—	W	6.6
"	25	0.445	0.173	0.413	—	NE	12.0
"	26	0.346	0.246	—	—	W	12.5
"	27	1.210	0.176	0.324	0.105	W	12.1
"	28	0.436	0.204	0.453	0.117	S	12.5
"	30	0.319	0.229	0.332	0.074	NE	6.9
1952							
January	2	1.022	0.190	0.224	0.084	N	5.5
"	3	0.361	0.218	0.305	0.055	W	10.9
"	4	2.706	0.238	0.297	0.170	E	8.4
"	11	0.445	0.185	0.491	0.00	SW	12.1

31, 1951, there was no marked diurnal variation, and the frequency of light, medium, and heavy fumigations occurred in normal sequence. In the period, April 1 to May 22, the fumigations were also nondiurnal in character, but the frequency of the medium fumigations was higher than that of the light fumigations. The occurrence of heavy fumigations was markedly greater in this period than in the preceding three months. The plot of the data during the period, June 18 to August 31, reveals a diurnal rhythm in the incidence of medium and heavy fumigations with peaks occurring in the morning and late afternoon periods of the day. The frequency of low fumigations is highest during the period from early evening to midnight. During September 1 to October 31, the frequencies of medium and of heavy fumigations tend to increase. The medium fumigations show peaks in frequency in the morning and late evening periods. During the months of November and December the medium and heavy fumigations predominate, the former showing a well-defined peak in frequency during the late afternoon, whereas the heavy type shows two minor peaks, one occurring at about 10:00 A.M. and the other in the late afternoon to early evening.

A comparison of the frequency distributions at the various Thomas autometer stations is shown in Table III. The seasonal trend in pollution discussed above is also indicated by the data in this table.

These results indicate that there are two periods of the year in this area when the pollution load is heaviest, the spring period of April and May, and the late fall and early winter period of November and December. Studies are now under way to determine whether the chronic effects of air pollution on public health would show their maximum measurable influence during such periods within the Detroit River Area.

Smog visitations of several days' duration have been noted during temperature inversion periods in the Detroit River Area. Such smog visitations showed their highest frequency of occurrence during the months of April, May, July, October, November and December. Relatively high peak concentrations of sulphur dioxide have been noted during such visitations. On many occasions the area has been blanketed with higher than usual contamination for a distance of fifteen miles from the Detroit River. As shown in Table IV, such visitations occurred on nine occasions in November, and on fourteen occasions in December of 1951. At the two stations showing the highest concentrations, the short period maxima reached 0.979 and 1.105

TABLE V.
CONCENTRATION OF GASEOUS CONTAMINANTS IN WINDSOR AREA

	Hydrogen Sulfide			Chlorine			Oxides of Nitrogen as NO_2			Ammonia		
Location	No. of Samples	Mean ppm	Max. ppm	No. of Samples	Mean ppm	Max. ppm	No. of Samples	Mean ppm	Max. ppm	No. of Samples	Mean ppm	Max. ppm
D. M. Ferry Building	21	.092	.607	15	.086	.618	8	1.740	3.480	9	.199	3.070
Peter Street	10	.203	.527	5	.066	.112	1	1.270		3	.422	0.820
Walker Road	4	Zero	Zero	3	.054	.093				3	.186	0.263
Ambassador's Park	2	.115	.231				2	0.237	0.453	4	.216	0.540
Postum Co. (Wellington near Wyandotte)	4	.232	.600									
Assumption Church	1	Zero					1	0.030		1	.537	
Caron & Sandwich	4	.048	.055	3	.142	.153	6	0.128	0.275	4	.483	1.38
Marentette & Sandwich				1	.190		1	0.930		1	.145	
Jackson Park				1	.125					1	.032	
Giles & Windsor				1	.018		1	0.568		1	.123	
Janette & Giles				1	.161		1	0.968		1	.089	
Tecumseh & Chandler				1	.018		1	2.570		1	.062	
Peter & Chappell							3	0.240	0.524	1	.707	
Reginald & Cadillac	1	Zero		3	.117	.177				1	.111	
Walker & Mohawk	1	Zero		1	Zero							
Mill St. Dock				3	.097	.155				3	.031	.079
Reaume Park				6	.144	.054				4	.104	.294
Willisted Park				1	.216					2	.020	.041
Essex Terminal				2	.063	.074				1	.082	
Stogell Park				1	Zero							
Total, Mean & Max.	49	0.108	0.607	48	.095	0.618	25	0.889	3.480	41	.216	3.070

ppm in November, and 1.210 and 0.824 ppm in December. An all-time peak of 2.706 ppm for four minutes was recorded on January 4, 1952.

In the light of what is known of pollution in other industrial areas, such peak concentrations, as well as the mean values mentioned previously, indicate more serious sulphur dioxide conditions in the Detroit River Area than in polluted zones such as Los Angeles,[13] Yonkers, N.Y.,[20] some of the industrial regions in Great Britain, and even the Trail, B.C. area,[10] before the full employment of remedial measures. The possibility of a major disaster in the Detroit River Area is rendered unlikely only on the ground of its topography, but, with increasing industrialization, toxic levels of pollution are being built up to serious proportions.

OTHER GASEOUS CONTAMINANTS: Among other toxic gaseous contaminants which have been found in this area are hydrogen sulphide, chlorine, oxides of nitrogen, and ammonia. The data on mean and maximum concentrations of these pollutants from

TABLE VI.
COMPARATIVE DATA FOR CONTINUOUS AIR SAMPLING STATIONS

(Mean daily values of aerosol contaminants at all filtration stations, and of gaseous contaminants at Thomas autometer stations, calculated as SO_2, in the Greater Windsor Area)

		Aerosol Concentration		Sulfur Dioxide Concentration			
Date, 1951		No. of Stations	Daily Average mg./cu. m.	Daily Average 3 Windsor Stations, ppm	Daily Average McGregor, Ont., ppm	Mean Wind Direction	Mean Wind Velocity, mph
October	24	22	.170	.036	Zero	SW	12.8
"	25	24	.218	.058	.008	W	4.3
"	26	23	.222	.061	.005	SW	6.0
"	27	15	.233	.058	.004	W	4.7
"	28	19	.175	.069	Zero	NW	8.7
"	29	23	.180	.069	.003	SW	6.9
"	30	24	.220	.063	.004	S	5.7
"	31	24	.128	.052	Zero	NW	12.6
November	1	22	.189	.064	.007	NE	4.6
"	2	24	.152	.055	.011	N	7.0
"	3	21	.091	.037	Zero	S	10.9
"	4	21	.103	.049	Zero	SW	16.2
"	5	20	.128	.059	.004	W	6.3
"	6	16	.081	.045	Zero	E	12.5
"	7	16	.104	.032	Zero	SW	7.4
"	8	18	.159	.053	Zero	W	13.2
"	9	18	.235	.094	.005	SW	9.2
"	10	17	.260	.085	.004	SW	7.7
"	11	16	.135	.072	.004	NW	1.7
"	12	19	.067	.055	.003	S	10.9
"	13	17	.100	.053	Zero	S	17.5
"	14	19	.131	.043	Zero	SW	19.5
"	15	16	.160	.050	.003	W	12.5
"	16	16	.144	.049	.003	N	12.0
"	17	15	.080	.033	Zero	NW	15.1
"	18	16	.098	.020	Zero	W	16.6
"	19	16	.165	.047	.008	NW	13.4
"	20	16	.115	.057	.019	NW	6.1
"	21	16	.107	.053	.002	S	12.5
"	22	15	.093	.056	.002	SW	15.5
"	23	18	.170	.046	.001	NW	6.4
"	24	18	.146	.036	Zero	NW	8.3
"	25	20	.154	.059	Zero	SE	5.9
"	26	21	.148	.047	Zero	W	19.6
"	27	19	.092	.061	.002	N	8.8
"	28	20	.220	.052	Zero	SW	10.0
"	29	21	.169	.064	.002	SW	8.2
"	30	20	.202	.080	.009	SW	9.0
December	1	21	.190	.065	.006	SW	8.4
"	2	20	.166	.069	.004	SW	6.8
"	3	21	.134	.063	.004	S	10.8
"	4	20	.257	.060	Zero	SW	9.9
"	5			.071	Zero	E	6.1

samples collected at intermittent intervals are shown in Table V. Determinations on 49 samples for hydrogen sulphide yielded a maximum of 0.607 ppm with a mean of 0.108 ppm. Forty-eight samples collected for chlorine determinations yielded a maximum of 0.618 ppm with an average of 0.095 ppm. Oxides of nitrogen calculated as NO_2 were determined by the phenoldisulphonic acid method on 25 samples, with a maximum of 3.48 ppm and an average of 0.889 ppm. Finally, 41 samples were analyzed for ammonia and they showed an average of 0.216 ppm with a maximum of 3.07 ppm.

It is obvious that the data obtained for such other gaseous contaminants are meager in comparison with the continuous sulphur dioxide observations. One cannot, therefore, assess the average risk upon exposure to the above contaminants. The data merely serve to indicate the nature of the hazard.

Suspended Particulate Matter

THE ZONES of high, medium, and low pollution with reference to aerosol concentrations have been investigated in the Greater Detroit-Windsor area by continuous high volume filtration units set up at about 31 stations on the U.S. side, and at 25 stations on the Canadian side of the International boundary. These units sample the air at a rate of about 50 cfm and collect the aerosol contaminants on specially prepared pleated paper filters. The filters are changed every 24 hours, and sufficient material is collected for the determination of the mass concentration and for chemical analysis.

High concentrations of particulate matter usually coincide with periods of smog and relatively heavy sulphur dioxide fumigations. The fluctuations in the daily means of particulate matter at all stations and in the daily means of sulphur dioxide at the three Windsor stations, and at Mc-

TABLE VII

Average, Minimum and Maximum Concentrations of Particulate Contaminants in Air From Continuous Filtration Samples Collected Daily at 26 Sampling Stations in the Greater Windsor Area During the Period, October 24, 1951 to December 5, 1951

	Air Sampling Station and Location	Milligrams per cubic meter			No. of Samples	Date of Minimum Weight	Date of Maximum Weight
		Mean	Minimum	Maximum			
	HEAVILY POLLUTED AREAS						
D	Windsor, near Detroit River	0.200	0.093	0.459	24	Nov. 6	Oct. 30
H	Windsor, near Detroit River	0.200	0.112	0.318	9	Oct. 31	Oct. 29
I	Windsor, near Detroit River	0.177	0.050	0.379	38	Nov. 12	Dec. 4
J	Windsor, near Detroit River	0.216	0.092	0.402	18	Nov. 12	Aug. 29
K	½ mi. S. of river	0.214	0.036	0.448	24	Sept. 6	Dec. 4
L	1½ mi. S. of river	0.238	0.082	0.436	28	Oct. 31	Nov. 25
P	near Detroit River	0.222	0.084	0.467	46	Nov. 12	Dec. 4
Z	Walkerville, 1½ mi. S. of river	0.204	0.059	0.378	33	Nov. 12	Nov. 30
	AREAS OF HEAVY TO MODERATE POLLUTION						
C	West Windsor	0.174	0.027	0.350	33	Oct. 6	Dec. 4
E	Near Detroit River	0.169	0.037	0.334	41	Nov. 28	Nov. 10
F	¾ mi. S. of river	0.180	0.032	0.325	30	Nov. 6	Nov. 29
G	1½ mi. S. of river	0.188	0.012	0.421	37	Nov. 13	Sept. 7
M	2 mi. S. of river	0.166	0.024	0.521	47	Nov. 6	Sept. 5
N	1¾ mi. S. of river	0.154	0.001	0.556	56	Oct. 5	Dec. 2
O	Walkerville, 1 mi. S. of river	0.163	0.014	0.380	36	Nov. 6	Dec. 4
Q	¾ mi. S. of river	0.180	0.065	0.552	36	Nov. 14	Oct. 26
R	1¾ mi. SE. of river	0.155	0.026	0.280	30	Nov. 12	Oct. 29
	AREAS OF MODERATE TO LOW POLLUTION						
A	Sandwich	0.123	0.027	0.259	34	Nov. 4	Nov. 1
B	Sandwich	0.132	0.015	0.278	48	Nov. 17	Aug. 29
S	Walkerville, 2½ mi. SE of river	0.136	0.016	0.238	34	Nov. 13	Oct. 30
T	Sandwich East, 2¾ mi. SE of river	0.134	0.030	0.410	39	Sept. 26	Nov. 10
U	East Windsor	0.140	0.021	0.351	48	Nov. 13	Dec. 4
V	East Windsor	0.140	0.021	0.249	41	Nov. 3	Oct. 27
W	East Windsor, near river	0.140	0.034	0.322	44	Sept. 26	Nov. 10
	AREAS OF LOW POLLUTION						
X	Tecumseh, Ontario	0.086	0.012	0.204	34	Nov. 17	Oct. 24
Y	McGregor, Ontario	0.073	0.003	0.214	40	Sept. 16	Nov. 9

Stations B, C, G, J, K, M, N, P, T, U, W and Y were operated for short periods prior to October 24.

Gregor, Ontario, are shown in Table VI.

An attempt has been made to delineate areas of heavy, moderate and low pollution on the basis of the mean and maximum concentrations of particulate contaminants from the continuous filtration data. In general, the most heavily polluted areas on the Canadian side lie close to the Detroit River, up to a distance of about one and a half miles away from the river. The areas of heavy pollution also lie within the zones which contain the major industrial operations. The areas of moderate to low pollution are located in the zones to the east and south of Windsor with the lowest values of all shown by the sampling stations at Tecumseh and McGregor. There is about a three-fold increase in mean concentration of particulate matter between the lowest and the most heavily polluted areas (see Table VII).

The results of an area survey of aerosol concentrations by means of two thermal precipitators at intermittent sampling stations in the Greater Windsor area are shown in Table VIII. The instruments were transported to the various stations by two teams of observers. The degree of contamination has been compared with the results obtained at the corresponding continuous filtration stations. It is obvious that with the low sampling rate used with the thermal precipitator, most of the particles collected will be in the range of less than one micron in size. A high degree of contamination from thermal precipitator readings will therefore be due to the presence of a considerable number of smoke particles of small size, whereas the high volume filtration apparatus tends to collect some of the larger suspended particles of fly ash and dust, as well as the fine ones. It is therefore difficult to compare results giving the number of particles per cubic foot with mass concentration data. Another difficulty lies in the fact that at some stations an insufficient number of samples have been collected with the intermittent sampling technique. Probably the most serious objection to the use of such intermittent sampling technique is that it is not possible to compare results at all sta-

TABLE VIII.

MEAN AND MAXIMUM CONCENTRATIONS OF AEROSOL CONTAMINANTS IN AIR AT INTERMITTENT SAMPLING STATIONS IN THE GREATER WINDSOR AREA

(Samples collected by the thermal precipitator during period, May-November, 1951)

Location of Air Sampling Station	Number of Particles in millions per cubic foot		No. of Samples	Degree of Contamination at Corresponding Continuous Filtration Stations
	Mean	Max.		
HEAVILY POLLUTED AREAS				
Sandwich & Cameron	11.5	19.6	4	Heavy
Sandwich & Caron	15.4	106.0	30	Heavy
Lanspeary Park	10.7	21.3	8	Heavy to Moderate
Walker Rd. & Mohawk	12.3	46.0	10	Heavy to Moderate
Memorial Park	28.4	68.2	6	Moderate to Low
Pillette & Seminole	19.2	37.1	10	Moderate to Low
Stodgell Park	23.2	42.6	10	Heavy
Reginald & Cadillac	29.2	95.8	10	Heavy to Moderate
Byng & 3rd Concession	21.8	33.1	6	Moderate to Low
Chatham & Ferry	34.4	62.2	4	Heavy
Peter & Chippawa	18.0	25.3	4	Heavy to Moderate
AREAS OF HEAVY TO MODERATE POLLUTION				
Peter & Chappell	7.0	23.5	16	Heavy to Moderate
Mill St. Dock	6.4	7.7	4	Heavy
Elliott & McDougall	7.1	13.6	4	Heavy
Sandwich & Marentette	5.1	22.7	16	Heavy
Willestead Park	7.8	15.9	10	Heavy to Moderate
Sandwich & Pillette	9.5	17.2	6	Moderate to Low
Assumption Church	4.7	20.3	12	Heavy to Moderate
Tecumseh Blvd. & Chandler	9.2	21.1	8	Moderate to Low
D. M. Ferry Bldg.	6.5	33.2	53	Heavy
Caroline & Janette	6.6	15.0	8	Heavy to Moderate
AREAS OF MODERATE TO LOW POLLUTION				
Ambassador Park	3.9	22.3	26	Heavy to Moderate
College & Campbell	4.4	19.3	10	Heavy to Moderate
Jackson Park	3.8	11.8	10	Heavy to Moderate
Giles & Janette	2.3	7.9	12	Heavy to Moderate
Huron Lines & Tecumseh Blvd.	1.4	3.1	7	Moderate to Low

tions simultaneously and thus eliminate the variations caused by meteorological factors.

Deposited Matter

THE DISTRIBUTION of deposited matter, or dustfall, has been studied by analyses of data from 20 sampling sites in the Greater Windsor Area. In Table IX, the mean values for total solids, insoluble, soluble and other component impurities, are given in tons per square mile per month. In the heavily polluted area the mean dustfall for all stations is about 92 tons per square mile per month. In the heavy to moderate pollution area, the mean dustfall is 53.9 tons per square mile per month, whereas in the moderate to low pollution zones the mean dustfall ranges from 42.7 to 35.9 tons per square mile per month. Here, as in the case of the suspended particulate matter, there is also a threefold increase in pollution load in passing from the low to the heavily contaminated areas.

Within the heavily polluted areas the dissolved impurities at the dustfall stations show a high sulphate content and comparatively low pH values. The dustfall in the heavily polluted areas also contains a high amount of ash and combustible organic matter. It is more tarry in nature and the water-soluble fraction has a much greater acidic or corrosive action on the surfaces of some materials with which it comes in contact than the dust in the less polluted areas.

The reliability of the dustfall data was tested by the analysis of a number of duplicate sampling stations with the results as shown in Table X. In most instances the variation in the duplicate samples was relatively minor in character. The variation

TABLE IX.
DISTRIBUTION OF DEPOSITED MATTER (DUSTFALL) IN THE GREATER WINDSOR AREA
(Mean values for deposited contaminants in tons per square mile per month)

Station		Test Period	Total	Insoluble	Soluble	Tar	Other Combustible		Dissolved Impurities			
No.	Location	1951	Solids	(Water)	(Water)	(CS_2)	Matter	Ash	Sulphur as SO_4	Chloride	Lime	pH
					HEAVILY POLLUTED AREAS							
1	D. M. Ferry Bldg.	Aug. 13-Dec. 13	89.9	64.6	25.0	1.57	21.3	42.0	8.77	1.94	5.82	4.73
2	Roof of D. M. Ferry Bldg.	Aug. 22-Dec. 22	123.6	91.3	32.4	1.24	22.7	60.0	10.05	1.29	3.51	5.90
4	Windsor Star Bldg.	Aug. 23-Nov. 27	62.7	46.9	15.5	1.01	17.1	29.8	7.17	0.85	3.54	6.28
7	Peter St. Western School	Aug. 27-Dec. 4	94.3	74.7	18.4	1.08	21.6	52.3	10.15	1.28	4.51	3.88
8	Peter St. Western School	Aug. 27-Dec. 4	101.4	71.4	21.1	3.58	26.7	43.3	5.20	3.88	2.86	4.73
15	East Windsor Hospital	Aug. 23-Nov. 30	81.1	66.3	14.6	0.39	16.5	48.2	2.76	1.11	3.65	6.98
	MEAN		92.2	69.2	21.1	1.48	21.0	45.9	7.35	1.72	3.98	5.42
					AREAS OF HEAVY TO MODERATE POLLUTION							
3	529 Victoria Ave.	Aug. 22-Nov. 30	48.4	35.8	12.4	0.81	10.4	19.8	4.03	1.45	3.94	5.70
5	Assumption College	Aug. 23-Dec. 19	45.3	34.6	10.1	0.34	10.4	22.2	1.67	0.50	1.69	5.75
6	Assumption College	Aug. 23-Dec. 19	43.6	35.2	8.1	0.11	6.3	29.8	2.42	0.27	1.24	3.95
11	Kennedy Collegiate	Aug. 28-Dec. 19	54.4	42.8	11.2	0.51	13.6	27.0	1.03	0.74	1.02	7.10
12	Kennedy Collegiate	Aug. 28-Dec. 19	68.5	58.1	9.9	0.59	23.0	34.9	2.04	0.60	2.86	7.50
13	St. Mary's Chapel	Aug. 27-Sept. 27	54.9	48.6	4.6	0.47	18.5	39.3	1.69	0.97	0.85	7.70
18	Dorner's Market Pillette Rd.	Aug. 27-Dec. 11	63.9	43.7	21.1	1.12	10.9	31.6	2.48	0.41	2.97	6.30
19	Gordon McGregor School	Aug. 28-Dec. 11	52.1	41.2	10.2	1.01	10.5	25.1	3.97	0.84	2.15	6.48
	MEAN		53.9	45.0	11.0	0.62	13.0	28.7	2.41	0.72	2.09	6.31
					AREAS OF MODERATE TO LOW POLLUTION							
9	Essex Sanatorium	Aug. 24-Dec. 10	37.7	27.5	10.0	0.22	7.0	20.4	2.71	0.53	1.14	7.30
10	Essex Sanatorium	Aug. 24-Dec. 10	45.4	32.9	11.7	0.40	9.4	23.1	4.02	0.98	3.62	6.30
16	Lowe Vocational School	Aug. 28-Dec. 6	45.0	29.7	15.0	0.86	12.4	16.7	7.43	0.73	3.51	6.40
	MEAN		42.7	30.0	12.2	0.49	9.6	20.1	4.72	0.75	2.76	6.67
					AREAS OF LOW POLLUTION							
17	Hydro Station Walker Rd.	Aug. 24-Nov. 30	40.1	30.6	9.2	0.54	12.2	17.9	1.63	1.45	2.59	6.38
14	Tecumseh Post Office, Tecumseh, Ont.	Aug. 24-Dec. 11	41.4	29.7	11.6	0.83	13.3	16.2	0.90	0.29	1.16	7.23
20	McGregor, Ont.	Aug. 24-Dec. 6	26.1	20.3	5.6	0.45	7.6	14.1	3.78	0.98	1.61	6.83
	MEAN		35.9	26.9	8.8	0.61	11.0	16.1	2.10	0.91	1.79	6.81

between duplicates was greater in the more highly contaminated areas.

The average monthly dustfall pollution in the heavily contaminated area of Windsor is apparently greater than that reported for Chicago, Cincinnati, Los Angeles,[15] Toronto,[1] and for Pittsburgh in 1950.[5]

There is a considerable difference in the composition of deposited matter to suspended matter in coal-burning areas. Particles which remain suspended in city air may consist of 85% by weight of tar and combustible organic matter and only about 15% of ash, whereas deposited matter may contain upwards of 70% ash.[4] The distribution of ash and insoluble solids of large particle size is such that their rate of deposition diminishes with distance much faster than the rate of attenuation of suspended smoke and sulphur dioxide. This is due to the rapidity with which the relatively larger particles of ash and soot settle out of the air by gravity.

Nature of Suspended Particulate Matter

THE CHEMICAL nature of the inorganic components of the complex aerosols in this environment have been studied by methods of x-ray diffraction and by spectrographic analysis. About 20 metallic elements have been identified in varying amounts. The most abundant are calcium, silicon, aluminum and iron. Next in order of abundance are the elements magnesium, lead, copper, zinc and manganese. Elements found only in traces were nickel, molybdenum, chromium, tin, barium, titanium, cadmium, beryllium and vanadium. The mean, minimum and maximum values of these elements derived from the analyses of 23 samples of particulate matter are given in Table XI.

The X-ray diffraction work has led to the identification of calcium carbonate, silica, iron oxide (Fe_2O_3) and aluminum metal in these samples. Samples collected in the early fall were found to contain pol-

TABLE X.
VARIATION IN WEIGHTS OF COMPONENTS OF DEPOSITED MATTER AT DUPLICATE DUSTFALL STATIONS IN THE WINDSOR AREA
(Values in tons per square mile per month)

Station No.	Location	Test Period 1951	Total Solids	Insoluble (Water)	Soluble (Water)	Tar (CS_2)	Other Combustible Matter	Ash	Dissolved Impurities: Sulphur as SO_4	Chloride	Lime	pH
5	Assumption College	Aug. 23-Sept. 23	49.6	39.4	9.0	0.44	11.5	24.8	1.57	0.72	2.62	7.50
6	Assumption College	Aug. 23-Sept. 23	28.4	21.0	7.1	0.15	4.3	16.9	4.04	0.36	2.10	4.90
	MEAN		39.0	30.2	8.1	0.28	7.9	20.9	2.81	0.54	2.37	6.20
5	Assumption College	Sept. 24-Dec. 19	40.9	29.8	11.2	0.24	9.3	19.5	1.76	0.28	0.75	4.00
6	Assumption College	Sept. 24-Dec. 19	58.7	49.3	9.1	0.07	8.3	42.6	0.79	0.17	0.38	3.00
	MEAN		49.8	39.6	10.2	0.16	8.8	31.1	1.28	0.23	0.57	3.50
7	Peter St. Western School	Aug. 27-Sept. 27	93.5	82.6	8.3	0.83	29.0	49.2	7.27	1.33	2.30	5.40
8	Peter St. Western School	Aug. 27-Sept. 27	114.2	80.0	25.9	6.55	49.4	38.9	3.95	6.87	3.67	4.60
	MEAN		103.9	81.3	17.1	3.94	39.2	44.0	5.61	4.11	2.99	5.00
7	Peter St. Western School	Sept. 27-Dec. 4	95.0	66.8	28.4	1.32	14.2	55.3	13.03	1.22	6.71	2.35
8	Peter St. Western School	Sept. 27-Dec. 4	88.5	62.8	16.2	0.61	3.9	47.7	6.44	0.88	2.05	4.85
	MEAN		91.8	64.8	22.3	0.97	9.1	51.5	9.74	1.05	4.38	3.60
9	Essex Sanatorium	Aug. 24-Sept. 24	38.9	28.1	10.4	0.27	7.8	20.1	4.36	0.85	1.24	7.40
10	Essex Sanatorium	Aug. 24-Sept. 24	46.8	33.3	11.9	0.19	14.9	18.2	4.44	1.33	5.28	6.70
	MEAN		42.8	30.7	11.2	0.23	11.3	19.2	4.40	1.09	3.26	7.10
9	Essex Sanatorium	Sept. 24-Dec. 10	36.5	26.8	9.6	0.16	6.1	20.6	1.06	0.20	1.04	7.20
10	Essex Sanatorium	Sept. 24-Dec. 10	44.0	32.5	11.5	0.61	3.9	27.9	3.60	0.63	1.95	5.90
	MEAN		40.3	29.7	10.6	0.39	5.0	24.3	2.33	0.42	1.50	6.55
11	Kennedy Collegiate	Aug. 28-Sept. 28	64.4	51.9	11.7	0.63	17.4	34.5	0.89	1.41	1.94	7.20
12	Kennedy Collegiate	Aug. 28-Sept. 28	94.0	84.4	8.6	0.95	37.7	46.6	2.66	0.97	5.16	7.90
	MEAN		79.2	68.2	10.2	0.79	27.5	45.6	1.78	1.19	3.55	7.50
11	Kennedy Collegiate	Sept. 28-Dec. 19	44.3	33.7	10.6	0.38	9.8	23.5	1.17	0.07	0.09	7.00
12	Kennedy Collegiate	Sept. 28-Dec. 19	42.9	31.7	11.1	0.22	8.3	23.2	1.41	0.22	0.55	7.10
	MEAN		43.6	32.7	10.9	0.30	9.1	23.4	1.29	0.15	0.32	7.05

TABLE XI.
MEAN, MINIMUM AND MAXIMUM VALUES (IN MICROGRAMS PER CUBIC METER OF AIR) OF METALLIC ELEMENTS DERIVED FROM SPECTROGRAPHIC ANALYSES OF 23 SAMPLES OF PARTICULATE MATTER COLLECTED AT FILTRATION STATIONS IN THE WINDSOR AREA, OCTOBER 26-DECEMBER 4, 1951

Metallic element	Concentrations in micrograms per cubic meter of air		
	Mean	Minimum	Maximum
Silicon	6.21	1.05	20.84
Calcium	3.26	0.85	13.88
Aluminum	2.75	0.71	6.94
Iron	2.49	0.59	8.77
Magnesium	0.81	0.20	2.64
Lead	0.614	0.125	1.805
Manganese	0.281	0.064	0.910
Copper	0.247	0.013	0.830
Zinc	0.197	absent	0.89
Titanium	0.067	0.005	0.18
Tin	0.046	0.011	0.110
Molybdenum	0.034	trace	0.087
Barium	0.027	absent	0.18
Nickel	0.026	0.006	0.069
Vanadium	0.017	absent	0.28
Chromium	0.011	absent	0.042
Cadmium	0.008	0.001	0.046
Beryllium	0.006	absent	0.073
Total sample weight	195.6	71.3	450.1

1. Bismuth was found to be absent in 19 samples, traces were present in two samples, and concentrations of 0.056 and 0.027 micrograms/m^3 were found in two other samples.
2. Antimony, arsenic, cobalt, mercury and tungsten were found to be absent in every sample.

len grains of ragweed in considerable quantity.

Environmental Contamination

THE AIR POLLUTION disasters of the Meuse valley in Belgium[6] and Donora, Pennsylvania,[19] have shown conclusively that unrestricted and excessive contamination of the atmosphere under adverse meteorological and topographical conditions may lead to acute episodes involving sickness and death from respiratory and cardiovascular disorders. The chronic effects of air pollution are not so clearly defined, nevertheless the frequent occurrence of eye irritation and smog damage to vegetation in the Los Angeles area during temperature inversions illustrate that such influences are also present.[14,15] The Donora Report has stressed the significance of a synergistic effect in air pollution so that the combined influence of a number of toxic contaminants occurring simultaneously may be far greater than the additive effect of individual contaminants. The specific surface and adsorptive capacity of small aerosol particles for gases and vapors, the role of condensation nuclei and the deposition of sulphuric acid mist and other compounds on such nuclei may affect the respiratory system in a manner entirely different from that of similar concentrations and durations of relatively pure toxicants.

Statistics and correlations have been reported on the increase in deaths from respiratory disease during smog visitations in industrial communities in England.[12,18] The loss of sunshine and decrease in ultraviolet irradiation have been considered as contributing factors in the occurrence of deficiency diseases such as rickets,[2,11] However, some authorities still claim that the chronic effects of air pollution have never been demonstrated conclusively.[17] There is, as yet, little experimental work available on the effect of air pollutants on the health of humans and animals in the concentrations and under the environmental conditions approaching those of the atmosphere of cities and industrial areas. The permissible limits of exposure set by industrial hygienists for conditions inside industrial plants are based on the determination of safe limits for the relatively healthy working population over an eight-hour period. Exposure to atmospheric smog may occur during much more prolonged periods and involve the entire population, including those most susceptible, such as children under five years old, people over 60, and those suffering from asthma and various other ailments. It was the consensus at the conclusion of the U.S. Technical Conference on Air Pollution of May, 1950, that pollution with allergenic material of industrial origin is associated with a frequent and apparently increasing occurrence of acute and chronic disease, involving especially the respiratory tract and the skin.[16]

Although there may be some disagreement among authorities as to the magnitude of the chronic effects of excessive air pollution on public heath, nobody will deny the existence of adverse effects on public welfare. Huge economic losses have been sustained in city areas from the accelerated deterioration of buildings, structural materials, corrosion of metals, plant and household equipment, injuries to textiles and

other fabrics, and excessive laundry bills.[7] The frequent occurrence of smog in densely populated areas, accompanied by poor visibility, has caused serious and costly traffic dislocation at airports and on highways. In rural areas, the works of Katz,[9,10] Thomas[23] and others[21] have indicated that gas damage may result in retardation and killing of crop plants and forest growth, and erosion and poisoning of soils.

The environmental studies in the Greater Detroit-Windsor area are being correlated with investigations on community health, meteorology, safety, economy and vegetation. Studies of effluents from individual plant operations and the application of control measures, wherever necessary, are also in progress.

Major importance is attached to the biological aspects of this air pollution study which will be carried out concurrently on both sides of the Detroit River area. The first phase consists of a fact-finding study for one year which will provide: (a) an extensive review of existing health records in the area and also in a control area; (b) a pilot study to determine the best methods for conducting a sickness survey by enumeration, and to determine what health factors, or illnesses, are relevant as an index of measurement.

This will establish the methodology of collecting sickness experience in the population and determine what health factors appear to be related to pollution. The second phase will consist of a full scale sample survey of sickness or health in the cities of Detroit and Windsor, and control cities. This will be related to areas of high and low pollution and socio-economic levels. It is anticipated that the health investigation will take about five years. Other factors will also have to be related to sickness experience, including parallel studies of pollutants in the atmosphere, collection of meteorological data, and the effects on economy, safety and vegetation.

The health project is in the hands of a planning committee of representatives of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the health officers of Detroit and Windsor, and representatives of the State of Michigan and the Province of Ontario. This organization is a sub-committee of the Technical Advisory Board on Air Pollution to the International Joint Commission.

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Dust Particles in High Velocity Air Streams

REPRESENTATIVE SAMPLING

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An isokinetic sampler for aerosols has been developed for use on aircraft in flight. The sampler was designed to maintain air flow into its inlet isokinetic with the flow of the air stream to be sampled. Also it was designed to achieve high collection efficiency over a wide range of altitudes and air velocities collected by the sampler. The inlet is mounted on gimbals and is vaned to maintain its axis parallel to air flow lines.

The aerosol particles are precipitated electrostatically on glass slides, electron microscope screens and selected metallic surfaces. The theory of precipitation of particles for this type of sampler is treated briefly. Methods for study of the collected samples are discussed.

IN INVESTIGATING the properties of finely divided material dispersed in the atmosphere at high altitudes, it became necessary to develop a sampler capable of obtaining representative samples from an airplane in flight.

The major problems in developing the sampler resolved themselves into three classes: (1) those associated with the aerodynamic problems of representative sampling of aerosols in high velocity air streams; (2) those connected with development of an efficient precipitation unit capable of being integrated into the sampler; and (3) those involved with collecting samples in such form that the particles were individually available for study by such techniques as electron and optical photomicrography, autoradiography, and radiochemical analysis.

It is necessary, in obtaining statistical data on the properties of particles composing a cloud in the atmosphere, to ensure that the sample of the cloud's particulate matter is representative. If this sample is to be taken from an airplane in flight, additional difficulties are presented by the effect of the turbulence about the plane on the distribution of particles in the air. Furthermore, consideration must be given to the effect of curved streamlines around the inlet of the sampler because of the high relative velocity of the sampler and ambient air.

Fig. 1 shows the streamlines produced in air flowing parallel to the axis of a sharp-edged inlet in which the velocity of the air is 30% of the external stream being sampled. It can be seen that particles at points such as A in Fig. 1 are contained in curving streamlines, and are, therefore, subject to acceleration fields tending to move them at right angles to the streamlines.

Larger aerosol particles, having greater inertia, will move faster in such centrifugal fields than will the smaller particles, with the result that a non-isokinetic flow of this type will collect a nonrepresentative aerosol sample in which the larger particle sizes will be excessively represented. A flow condition in which the velocity

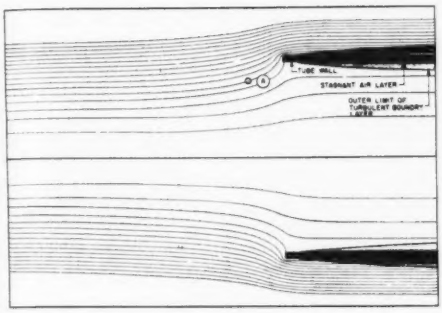

Fig. 1.
Flow net for air entering a hollow circular cylindrical aerosol sampling tube when $\frac{V_1}{V_0} = 0.33$, altitude 0 to 40,000 feet.

of air flowing into the inlet equals the velocity of the stream of air being sampled is termed isokinetic. In the case of a sharp-edged inlet operating at isokinetic flow, curved streamlines at the inlet are reduced to negligible proportions.

Since quantitative information concerning the extent to which non-isokinetic flow in an inlet alters the size distribution of particles entering the sampler was not available, it was decided to design the sampler so that flow into its inlet would be isokinetic at all times.

Fig. 2 shows a cross-sectional drawing of the sampler in its final form. The sampler is designed to be mounted outside and at the front of an aircraft in a region of laminar flow beyond the turbulent boundary layer which surrounds the aircraft. Air is drawn into a sharp-edged inlet at a velocity equal to the external stream velocity. The inlet is mounted on gimbal rings and vaned to ensure its alignment with wind velocity. The sample stream is led from the vaned inlet to the expansion section through a rubber tube specially molded to provide a smooth bore of uniform cross section. The expansion section, consisting of a smooth cone with a divergent angle of 7°, reduces the velocity of the sample stream from 150 to about 3.7 mph, at which velocity the electrostatic precipitator efficiently precipitates the particles of the sample. The cleaned air is exhausted to the atmosphere through the annular outlet around a choke which serves as a valve controlling the flow rate through the instrument. The external stream in passing the outlet provides sufficient pumping action to compensate for internal friction in the instrument and ensure isokinetic flow into the inlet.

Fig. 3 is a photograph of the assembled sampler. Fig. 4 shows a closeup of the vaned inlet and Fig. 5 shows a view of the choke section. A sliding high voltage connection was provided between the choke section and the precipitation chamber so that the latter would be quickly and easily removed and replaced.

Electrostatic precipitation for removing

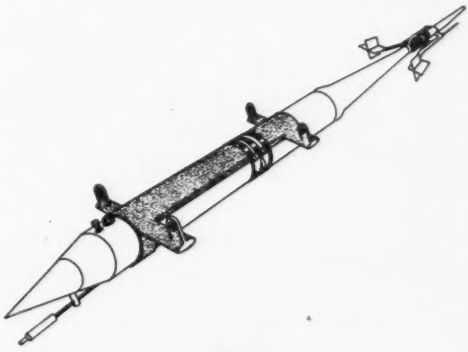

Fig. 2a.
Drawing of assembled sampler

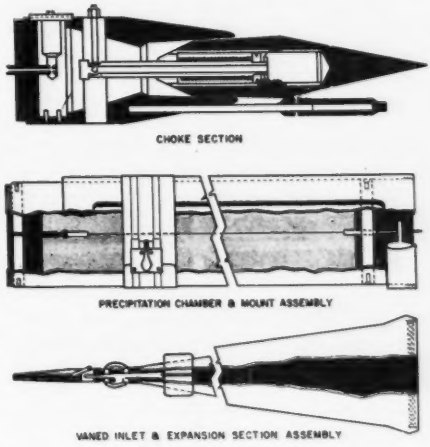

Fig. 2b.
Cutaway showing (1) choke section, (2) precipitation chamber and mount assembly, and (3) vaned inlet and expansion section assembly.

Fig. 3.
Assembled cloud sampler

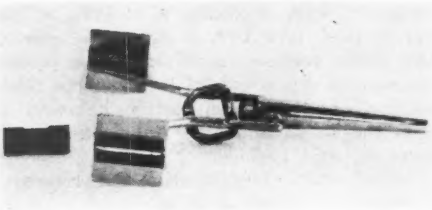

Fig. 4.
Vaned inlet

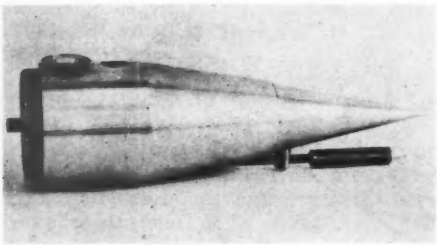

Fig. 5.
Choke section

the particles from the sample stream was chosen because it efficiently processes comparatively large volumes of air with minimum pressure drop in the air passing through the precipitator and because it can also be adapted to precipitate the particles directly onto surfaces from which they may be studied microscopically.

After a certain amount of experimental work involving various forms of electrodes, a single wire 10 mils in diameter, suspended concentrically inside the cylindrical outer electrode from a system of Lucite and Pyrex insulators, was chosen. This precipitator was tested in the system shown in Fig. 6. The test aerosol, alumina particles of known size distribution, was prepared by atomizing a water suspension of the particles and subsequently drying the spray by admixture with the intake air stream in the pressure reservoir. This aerosol passed into a mock-up of the precipitator to be tested. Both velocity and pressure of the inlet stream in the sampler mock-up could be controlled by adjustment of the two by-pass valves in the system, and in this way pressure and velocity corresponding to various altitudes in the range 14,000 to 30,000 ft. could be simulated. Efficiency of the precipitator was estimated by microscopic examination of optical slides and electron microscope grids placed at intersals along the length of the precipitation chamber. Fig. 7 shows a series of optical photomicrographs of particle deposits occurring at various distances from the front end of the chamber during a successful test run. Fig. 8 shows median particle diameters and particle concentrations as obtained from analysis of electron microscope grids exposed during the same test run.

Specifications for the power supply were obtained by measurement of breakdown voltage and limiting ion current in the pre-

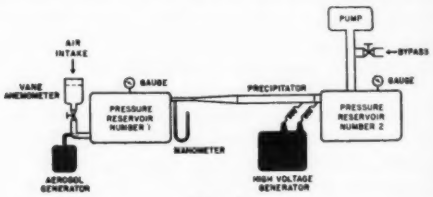

Fig. 6.
Diagram of apparatus used in testing of the precipitation unit.

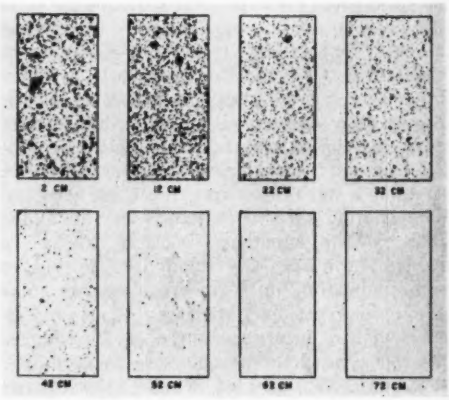

Fig. 7.
Optical photomicrographs of particle deposits at various distances from the forward end of precipitation chamber.

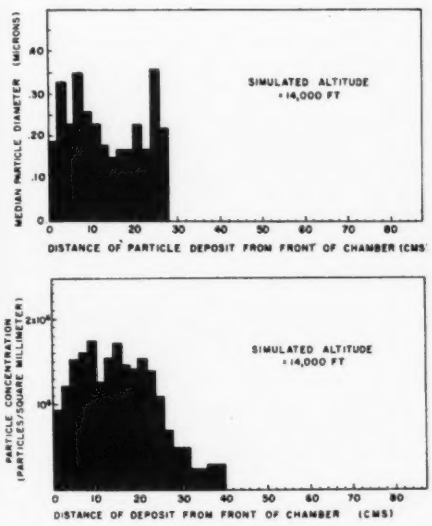
MEDIAN PARTICLE DIAMETER (MICRONS)
SIMULATED ALTITUDE = 14,000 FT
DISTANCE OF PARTICLE DEPOSIT FROM FRONT OF CHAMBER (CMS)
PARTICLE CONCENTRATION (PARTICLES/SQUARE MILLIMETER)
SIMULATED ALTITUDE = 14,000 FT
DISTANCE OF DEPOSIT FROM FRONT OF CHAMBER (CMS)

Fig. 8.
Particle concentration and median particle diameter as a function of distance of the deposit from the front of the precipitation chamber.

cipitator as a function of altitude between 14,000 and 32,000 ft. These measurements were made in a Bowser Environmental Simulator, in which the pressure, temperature, and humidity could be controlled to simulate conditions at these altitudes. Fig. 9 shows the breakdown voltage and maximum ion current of the precipitator as a function of altitude.

These curves show that, while the maximum ion current is nearly constant with altitude, the breakdown voltage decreases from about 23,000 v at 14,000 ft. to about 16,000 v at 32,000 ft. A transformer approximating these power characteristics was designed and built by Electro Engineering Company of Oakland, California. Variation of voltage was obtained by means of a variable inductance placed in series with the primary. This inductance could be set to provide nearly optimum voltage output at each sampling altitude. The system was designed with minimum power regulation so that surges in current due to arcing in the precipitator would cause the voltage to drop for a sufficient length of time to extinguish the arc.

The power supply for the electrostatic precipitator and the controls for the sampler were contained in the power pack which was mounted inside the aircraft, and was connected to the sampler through leads running through a fairing. When the sampler is not operating, the choke remains all the way forward, in which position it prevents any flow of air through the sampler. Sampling is started by the introduction of compressed air to the cylinder inside the choke, which forces the choke back against the stop nut at a position previously calibrated to provide isokinetic flow in the inlet. Since the velocity in the inlet is very sensitive to the area of the annular opening around the choke, this member was constructed in the form of a tapered plug, so that adjustment of the choke stop nut position would be less critical.

Calibration of air flow through the instrument was done in flight by adjusting the position of the choke valve with the stop nut. Identification of a state of isokinetic flow in the inlet was made by comparison of the static pressure inside the inlet two diameters downstream from the leading edge with that in the external stream outside the inlet. Equality of the static pressure at these two points indicated isokinetic flow into the inlet within about 1%. The choke setting required for isokinetic flow into the inlet did not vary with altitude between 14,000 and 32,000 ft., nor

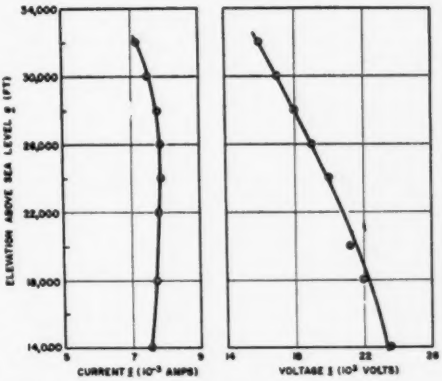

Fig. 9.
Breakdown voltage and limiting ion current of the electrostatic precipitator as a function of altitude.

did it vary with stream velocity between 125 and 200 mph.

In sampling clouds with this instrument, precipitation chambers were lined with copper foil one mil in thickness to permit removal of the sample from the tube for radiochemical analysis. Optical microslides, consisting of 5.5 by 7.3 mm rectangular pieces of microscope cover glass, and electron microscopic grids were fastened to the liners alternately at 2 cm intervals along the length of the tube. Sampling slides with nonconducting surfaces were found to repel particles, apparently because of the accumulation of static charge on the surface from the ion current flowing to the wall of the precipitator. It was found necessary to form an electrically grounded conducting film on these surfaces by condensing a very thin transparent coat of aluminum on them. This aluminum coat was grounded to the base strip with Aquadag conducting cement.

The precipitation chamber of the cloud sampler is an electrostatic precipitator of the cylindrical type with a central wire electrode. The chamber is of uniform cross section, and factors governing precipitation efficiency, such as intensity of the ion current and the shape and strength of the electrical field in the chamber, are uniform inside the chamber, except in the region near the ends of the central electrode. It seems probable that the rate at which particles are precipitated from any small volume of air in the central portion of the chamber depends on the number of particles present in that volume.

$$\text{Thus } -dC = p\frac{\pi D^2 C}{4}dL \qquad (1)$$

where C = concentration of particles suspended in the air per unit volume
D = diameter of the chamber,
p = a constant,
and L = distance from upstream end of the precipitation chamber.

In this equation, $\frac{\pi D^2 C}{4}dL$ represents the number of particles which are contained instantaneously in a length dL of the chamber; $-dC$ is the decrease in C during the time that the particles occupy this volume.

Upon integration, $C = C_o e^{-nL}$ (2)
where C_0 = concentration of particles per unit volume in the air entering the precipitation chamber,
and $n = p\frac{\pi D^2}{4}$ = a constant.

This equation expresses the decrease in concentration of particles in the air passing through the sampler as a function of the length of the precipitation chamber traversed.

If S = precipitated particles per unit area on the inside surface of the precipitation chamber at any point,

$$S = \frac{vt\,\pi D^2/4}{\pi D}\frac{dC}{dL} \qquad (3)$$

where v = velocity of air passing through the chamber,
and t = time of sampling the cloud.

The numerator of the fraction on the right is the amount of particulate matter precipitated from the length dL of the chamber and the denominator is the area over which the particles are deposited.

$$S = \frac{vtD}{4}\frac{dC}{dL} \qquad (4)$$

$$\text{From (1), } \frac{dC}{dL} = \frac{-p\pi D^2 C}{4} = -nC$$

$$\text{and } S = \frac{-vtDnC}{4} \qquad (5)$$

For any two specific values of C, such as C_1 and C_2 corresponding to L_1 and L_2:

$$C_1 = C_o e^{-nL_1}$$
$$C_2 = C_o e^{-nL_2}$$

$$C_1/C_2 = e^{n(L_2 - L_1)} \qquad (6)$$

$$\text{and } \log C_1/C_2 = n(L_2 - L_1) \qquad (7)$$

Since S is proportional to C,

$$\log S_1/S_2 = n(L_2 - L_1). \qquad (8)$$

In sampling of clouds containing radioactive particles, if S, the number of radioactive particles per unit area on the inside surface of the chamber, is proportional to A, the amount of radioactivity per unit area on the surface at that point, then

$$\log A_1/A_2 = n(L_2 - L_1). \qquad (9)$$

From samples of radioactive clouds collected with the instrument values of A and L were obtained from the count of radioactivity deposited on the optical microscope

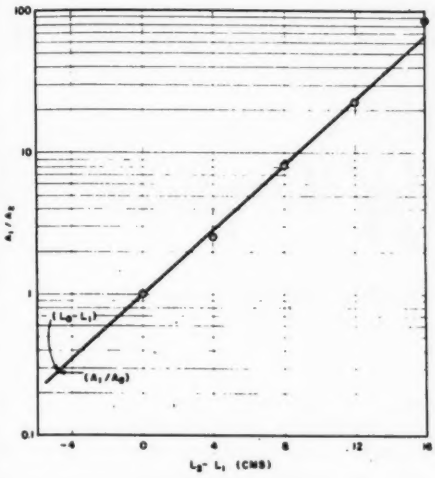

Fig. 10.

Particulate β Radioactivity deposited on the wall of the precipitation chamber as a function of its distance from the forward end of the central electrode.

surfaces located at known positions in the chamber. The last equation was chosen for plotting, because the region of the chamber for which the equation is valid is the region of uniform field and ion current. The field around the forward end of the wire varies with L. Using this equation, a value A_1 can be chosen corresponding to L_1 which is beyond the region of end effects and at which point the field is uniform. Succeeding values of A_2 and L_2 can then be compared to the same value of A_1 and L_1 to the limit of particle deposit in the chamber.

Plots of this equation prepared for the collections were made on semilog paper as shown in Fig. 10. The slope of the resulting straight line gave values of n, which is a measure of precipitation efficiency of the precipitator. As can be seen from the above development, n is the fraction of the particulate matter, suspended in the air contained in an increment of length, which is precipitated per unit length of flow down the chamber.

By extrapolation of the semilog plot, Fig. 10, values of A_0 can be determined corresponding to the value of A at the forward end of the precipitation chamber if there were no end effect of the central wire electrode. Using the values obtained for the time, t, during which each sampler was inside the cloud, values of C_0, corresponding to the amount of radioactivity per unit volume in the air entering the precipitation chamber, were computed.

An independent method of computing C_0 consists of calculating the total amount of particulate radioactivity collected in the sampler by integrating under the curve of radioactivity per unit area on the chamber wall versus chamber length and dividing the result of the integration by the volume of air sampled.

If A_t = total integrated amount of particulate radioactivity deposited in the chamber,

$$\text{then } A_t = \frac{vt\pi D^2 C_0}{4} \qquad (10)$$

$$\text{and } C_0 = \frac{4A_t}{vt\pi D^2} \qquad (11)$$

Computation of C_0 by these two independent methods produced values whose averages agreed within 8%. This agreement supports the hypothesis of exponential decrease of concentration of particulates in the air passing through the sampler as a function of the length of precipitation chamber traversed, since one method of calculation of C_0 is based on this assumption. This hypothesis predicts an extremely high efficiency of the precipitation chamber in removing particulates from the air sampled.

Since $C/C_0 = 1 - \text{Efficiency}$

$$\text{Efficiency} = 1 - e^{-nL} \qquad (12)$$

where L = the length of the precipitation chamber, 75 cm.

On this basis, the precipitation efficiency for the collections varied between a minimum of 99.97% and a maximum percentage of $100 - 8 \times 10^{-11}$. These orders of precipitation efficiency are supported by the complete absence of radioactive particles on the slides placed in the rear half of these precipitation chambers.

ACKNOWLEDGMENT: We are deeply indebted to S. J. DeFrance, Director of the Ames Aeronautical Laboratory, Moffett Field, California, and to Miles Erickson, Emmett Mossman, and Robert Peterson, members of the staff, for aid in the design and aerodynamical testing of the sampler.

FLUORIMETRIC DETERMINATION of *trace amounts of beryllium*

GEORGE WELFORD and JOHN HARLEY, Analytical Branch
Health and Safety Division, New York Operations Office
U.S. Atomic Energy Commission

The published sensitivity of Morin as a reagent for the detection and determination of beryllium led to a further investigation of this reagent. A procedure is outlined for the chemical separation of beryllium and subsequent fluorimetric analysis. A fluorimeter developed by the New York Operations Office, Instrument Branch, allows the detection of 0.005 micrograms of beryllium per sample.

A METHOD sensitive enough for toxicological studies, without the use of the spectrograph, would make it possible for smaller laboratories to analyze for beryllium. The published sensitivity of Morin[1,2] as a reagent for the detection and determination of beryllium led to a further investigation of this reagent. The chemical separation, published in "Analytical Chemistry"[3] using oxine (8-hydroxquinoline) has been found adequate for fluorimetric analysis of air dust samples. Urine and other biological materials are separated by an ion exchange procedure[4] soon to be published.

Analytical Method[3]

THE FILTER paper containing the sample to be analyzed is wet ashed, treated with hydrofluoric and sulfuric acids, and taken to dryness. After solution in hydrochloric acid, the iron, aluminum, and other metals are removed by precipitation with oxine in acetate-buffered solution. The excess oxine is removed with chloroform, and the beryllium is precipitated using 2.5 mg of aluminum as a carrier. The precipitate is dissolved and made up to five milliliters with one normal sodium hydroxide. Triplicate one milliliter aliquots are treated with one milliliter of 0.0001% morin, diluted to five milliliters and the fluorescence measured.

Instruments[7]

THE FLUORIMETER was designed and built by the Instruments Branch of the Health and Safety Division. It has a sensitivity of 0.005 micrograms and is linear over a range of 100.

A General Electric AH-4 100 Watt lamp is the source of ultraviolet, and a multiplier photo-tube, amplifier, and micro-ammeter are used in the measuring circuit. Four solution cells, of five milliliter capacity, are held in a slide, the ultra-violet entering at the side and the fluorescence being measured at the top. This allows blank and triplicate samples to be measured in rapid succession.

A 0.01% quinine sulfate solution is used to set the high end of the scale, varying the phototube voltage until the quinine solution reads 20,000 scale units. The total scale range is 100,000 units using four decade scales. The blank reading is about 40 units and 0.01 micrograms of beryllium gives an average reading of about 20 units above the blank.

The Fisher Nefluoro-Photometer gives a blank of 12% and with 0.01 micrograms of beryllium the reading is 18%. The tubes hold a larger volume approximately 15 ml

TABLE I.

Micrograms Be Present	Deflection
0.0025	4
0.005	12
0.01	19
0.025	41
0.05	83
0.075	128
0.1	149
0.2	259

(Reading-Blank—Deflection)

TABLE II.

Micrograms Be Present	Deflection
Blank	120
0.1	500
0.2	880
0.5	1600
1.0	2200
2.0	2800

and the fluorescence is measured at right angles to the incident light. The use of this instrument is restricted since it is only linear over a range of 10.

Some preliminary work was also done with the Beckman Instrument with the fluorescent attachment. This instrument offers possibilities but is not as sensitive as the instrument described here. Some published work gives additional information concerning the Beckman.[5]

Experimental

PURITY AND CONCENTRATION OF MORIN: A 1% acetone solution of technical grade morin as purchased from Eastman Kodak was originally used. Further dilutions were made in absolute ethyl alcohol. This morin in a NaOH concentration of 0.2N per tube gave very high blanks which ranged from 26 to 34 on the thousand scale. These values, on the lower end of the least sensitive scale, are undesirable. Further dilutions did not increase the ratio of beryllium to blank to a workable difference.

A method of purification of morin modified from that of J. F. Bonner,[6] University of Rochester No. UR-111 has been used successfully. A 1% solution of morin in acetone is used as the basis for further dilutions with distilled water. This solution is stable for months if kept in the dark. This reagent gives a reagent blank of 40 deflection units at a 0.0001% concentration.

Table I shows the increase in fluorescence with increasing beryllium concentration. Above 0.2 of a microgram of beryllium the fluorescence levels off. In order to gain a wider range it was necessary to increase the morin concentration. Table II shows the results with 0.0005% morin.

Results above 2.0 micrograms are not reliable and a dilution is recommended.

Fading

ONE OF THE outstanding faults of the fluorimetric method is the rapid fading of the morin beryllium fluorescence. This is illustrated in Table III.

TABLE III.
FADING OF FLUORESCENCE

Exposed to U.V.	0	5	10 (min)
Blank	31	29	27
0.005 ug Be	39	33	30
0.50	580	440	370
Not exposed to U.V.			
Blank	33	31	29
0.005 ug Be	41	37	34
0.50	580	490	440

As can be seen from the data, there is an initial drop in the readings on samples containing beryllium, which is proportionally greater than that for the blanks in the initial five minutes. The greatest proportional decrease is observed in the 0.5 microgram Be sample. Exposure to ultra-violet increases the rate of fading, but this should not be serious, as readings are made rapidly.

The greatest instability appears to be during the 10-20 minute interval. It is advised that readings be taken within one minute after addition of morin to the sample. This will prevent the loss in sensitivity which occurs in a 10-20 minute interval and minimize any fading that may occur. This is the practice carried on in our laboratory.

Reproducibility

STANDARD BERYLLIUM solutions were made up in polyethylene bottles containing 2.5 mg of aluminum per 10 ml. and 1N NaOH. One ml of these solutions was pipetted into the fluorimetric cells and run a month apart with the results given in Table IV.

As a result of this experiment the stability of the instrument, analytical curve, and the morin solution seems fixed.

TABLE IV.
REPRODUCIBILITY OF ANALYTICAL CURVE

Ug Be	1	2	3
0.0025	4	5	4
0.005	12	11	10
0.02	29	25	24
0.10	220	229	222

Concentration of Alkali

EXTENSIVE factorial work was done to determine the best NaOH concentration for the maximum sensitivity of the reagent.

It was found that 0.2N NaOH gives optimum results. This factor is critical in the determination.

Interferences

CALCIUM and magnesium were the elements of main interest since they were not completely separated chemically. The final solution may contain 14 mg of each element without effecting the recovery of known amounts of beryllium.

Recovery

KNOWN AMOUNTS of beryllium have been periodically added to filter papers and carried through the regular analysis. The over-all recovery of over 200 analyses was on the order of 92%. Listed in Table V are some of the analyses which were selected at random.

Each step in the procedure has been checked with radioactive Be^7 as a tracer with excellent recoveries.

TABLE V.

Micrograms Be Added	Micrograms Be Found	% Recovery
1.0	0.96	96
25	20	80
25	25	100
9.0	8.0	89
3.0	2.6	87
0.01	0.01	100
0.06	0.055	92
0.03	0.02	67

This method has been in routine use in our laboratory for over a year and is thus recommended for rapid accurate beryllium analysis.

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7. Information concerning this instrument is available by writing: Instruments Branch, Health & Safety Division, New York Operations Office, U.S. Atomic Energy Commission, P.O. Box 30, Ansonia Station, New York 30, New York.

Industrial Hygiene Surveys
Toxicological & Chemical Problems

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Research in Instrumentation for Prevention of Industrial Health Hazards

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The Microdetermination of Ozone

PRELIMINARY STUDIES

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THE ANALYSIS of air for minute amounts of ozone is difficult to perform with any degree of accuracy or precision. Many methods have been proposed and published, but few are reliable when actually tried, and others are open to considerable theoretical criticism. Elkins,[5] in fact, states simply that there are no satisfactory methods for small amounts of ozone. The maximum allowable concentration of ozone is a poorly established figure, and the analyst is probably more to blame for this uncertainty than is the toxicologist.

Historically, potassium iodide has been used to determine ozone for many years, and a wide variety of methods using this reagent may be found in the literature. A detailed criticism of these many methods is not possible in a paper of this length, but all can be said to suffer for one or more of the following reasons: (1) doubtful accuracy, (2) interference by other gases, (3) necessity for sampling equipment unsuitable for field use, (4) excessive volume of air required for adequate sensitivity.

Because of these objections to the use of potassium iodide, various other reagents have been used, most of which are organic compounds. No attempt is made here to compile all of the published methods for ozone, but two were of particular interest, and were studied in considerable detail. These methods utilized fluorescein as the ozone determining reagent, and appeared most promising because of their extreme sensitivity and reported specificity. Several months of research were devoted to a study of the methods originally proposed by Egorov,[4] and Benoist,[1] but all data acquired to date has shown that both methods are empirical and unreliable. Oxidation of the non-fluorescent leuco-base of fluorescein to fluorescein is an extremely sensitive means of detecting ozone, but no conditions have yet been found which permit the quantitative estimation of the amount sampled as claimed by Egorov. Use of ozone's ability to bleach fluorescein as described by Benoist, is much less sensitive and sampling results are extremely erratic. Fluorescein cannot, therefore, be recommended, although it is planned to conduct further research with the reagent.

In view of the failure to establish a non-iodometric method of ozone determination, a study of published methods utilizing potassium iodide was begun. A means was sought whereby the objections to such methods previously cited could be overcome, and all experimental work to date indicates that the method to be described is satisfactory. A fundamental handicap plagues the researcher when dealing with micro quantities of ozone, for no practical methods of establishing the absolute amount of ozone being sampled are available. The physical methods which serve admirably for large amounts of ozone are not sufficiently sensitive for microgram quantities, and dilution of known high concentrations is uncertain, owing to the instability of the ozone molecule. For these reasons, the method of study chosen consisted of sampling ozonized oxygen with two absorbers in parallel. Agreement between the two samples thus establishes that any reagents being compared are either in error by the

Presented before the 13th Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, April, 1952, Cincinnati, Ohio.

TABLE I.
EXPERIMENTAL DATA

Sampling Solution	Rate, ml/min.	Time min.	PPM O_3 Found	
25.0 ml 1% KI, in NaOH	113	10	1.02	Identical
25.0 ml 1% KI, in NaOH	113	10	1.08	samples
25.0 ml 1% KI, in NaOH	113	10	1.43	Effect of varying
25.0 ml 1% KI, in NaOH	396	10	1.57	sampling rate
25.0 ml 1% KI, in NaOH	113	10	2.55	Effect of varying
25.0 ml 5% KI, in NaOH	113	10	2.27	KI conc.

same amount, or else both quantitatively fix ozone. To arbitrarily assume the latter is certainly not rigorous proof that a method is correct, but when agreement is consistently obtained with varying sampling rates, conditions of pH, etc., the likelihood becomes great that ozone is actually being quantitatively collected. Exemplary data of this sort is shown in Table I. It can be seen from the table that neither a four-fold difference in sampling rate nor a five-fold difference in potassium iodide concentration causes a serious deviation from the average ozone content of the air sampled, according to the method.

Experimental Procedure

OZONE was produced by irradiation of ordinary tank oxygen with ultra violet produced by a small mercury vapor lamp of the type now available for domestic use. Such lamps produce more than enough ozone for study purposes, and control of the amount sampled was achieved by varying the oxygen flow through the system, and by limiting the time of irradiation. The effluent stream of ozonized oxygen from a small glass chamber was divided into two parallel streams and all glass fritted absorbers of identical design were used to collect samples for analysis. Orifice flow meters were used to accurately measure the amount of ozonized oxygen sampled by each absorber. It was felt that this method of sampling effectively eliminated differences due to light, temperature and humidity. Blank determinations were always made by the same method, except that the ozonizing lamp was not turned on. With the exception of a few short lengths of tygon tubing used to make connections, the system was all glass, and errors due to reaction with other materials were thereby reduced.

A variety of analytical methods were used to determine the amount of ozone sampled, depending on the reagent used in the absorbing solution. Those used for the fluorescein studies will not be described, inasmuch as the reagent proved to be unsatisfactory. The method of sampling and analysis recommended as a result of this study is as follows:

EQUIPMENT: (1) Gas washing bottles, Corning catalog # 31760, capacity 125 ml. frit porosity—coarse. (Note—all work to date has been done with this absorber, but it is felt that collection efficiency is very high and other gas washing bottles will serve equally well.) (2) Pump—Willson pump or other suitable unit. (3) Spectrophotometer—Beckman model DU, tungsten light source and 1 cm Corex cells. (Any spectrophotometer capable of use at 352 mu should be acceptable.)

REAGENTS: (1) Alkaline potassium iodide, 1% KI in 1N NaOH. (Special grade KI, low in iodate recommended.) (2) Potassium iodate, reagent grade. Prepare 0.1N Master Standard and dilute as needed to make weak standards. (3) Phosphoric acid, reagent grade, 90%, dilute to 36%.

PROCEDURE: Draw air to be sampled through the gas washing bottle containing 25.0 ml. of alkaline potassium iodide solution, at a rate of 0.5 liters per minute. A glass wool filter plug on the intake side of the absorber is recommended for removal of most particulate matter when dirty air is to be sampled. A short piece of tygon tubing has been found satisfactory for this purpose.

After thorough mixing of the absorbing solution, withdraw a 10.0 ml. aliquot, add 2.0 ml. of 36% phosphoric acid, and let stand for about five minutes. This is best done in 25 ml. glass stoppered graduated cylinders which can be placed in a beaker of water to assist in cooling, although variations in temperature are not felt to be important. If the samples are suspected of containing dissolved peroxides, the aliquots should be brought to a boil, then acidified and cooled as stated, suitable volume corrections then being made.

The cooled solution is transferred to a

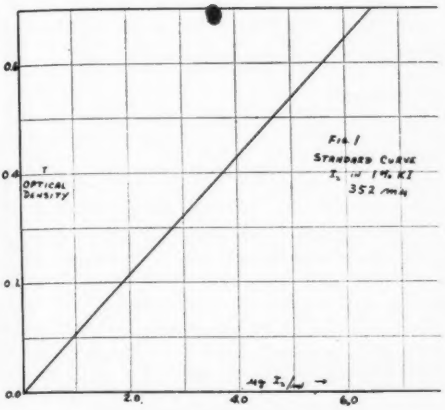

Fig. 1.
Standard curve I_2 in 1% KI 352 mμ.

Corex cell, and the percent transmittance read at 352 millimicrons, using distilled water as reference liquid. If the Beckman model DU is used, the ultra violet filter should be in place, and the blue sensitive phototube used. A reagent blank is run in identical fashion, and for most precise work, an air blank should also be run. Unlike neutral or acid potassium iodide solutions, however, the alkaline reagent is practically unaffected by oxygen, an so a reagent blank will usually suffice.

The standard curve shown in Fig. 1 is prepared by appropriate additions of potassium iodate standard solution to the potassium iodide sampling solution, and carrying out the above procedure. The curve thus obtained obeys Beer's Law throughout the range studied, namely from 0-10 micrograms of iodine per ml. of solution.

Discussion

IT WOULD quite obviously be better to use a fritted bubbler in a midget impinger flask, thus permitting a small pump to be used, and increasing the sensitivity of the method by reducing the volume of sampling solution needed. There is every reason to believe that such a sampling procedure is satisfactory, but as yet no studies have been made of the comparative efficiencies of the various absorbers available, and so the single absorber described is recommended as one which appears to be very efficient.

On the basis of preliminary experiments, peroxides do not interfere if the alkaline reagent is boiled before acidifying, and oxides of nitrogen interfere to a much lesser degree than with the neutral or acid reagent. It is believed, in fact, that future work will show that practically no oxidation of alkaline potassium iodide is caused by the concentrations of oxides of nitrogen ordinarily encountered.

In the absence of such data, however, some interference by oxides of nitrogen must be assumed.

Several papers have appeared in recent years which utilize the spectrophotometer to measure the concentration of the triiodide ion at 352 millimicrons. Custer and Natelson[3] studied the complete absorption spectrum of this ion and picked the 352 millimicron peak as being optimal for most work. A stronger peak exists at 288 millimicrons, but cannot be measured with the tungsten light source and Corex cells ordinarily used, and the gain in sensitivity is not sufficient to warrant acquisition of the ultra violet accessories needed by those laboratories not already possessing them. It is the conclusion of virtually all workers with micro quantities of iodine, that titrimetric methods are insufficiently sensitive for accurate determinations, and the spectrophotometric method is preferred.

The exact amount of phosphoric acid added to the alkaline reagent and the elapsed time after acidification are not critical, but blanks, samples and standards should be run in identical fashion. The strong acids may be used in place of phosphoric acid, but the amount necessary becomes more critical due to the lack of buffering action. Various objections to the use of alkaline potassium iodide have been raised in the past, but Boelter et al[2] have shown these to be unfounded in an excellent study on the determination of large amounts of ozone. Although the conclusions reached regarding large amounts need not necessarily apply to micro amounts, the present work indicates that such is the case.

Research is in progress to attempt to devise a means of preparing known micro concentrations of ozone, and thus establish the absolute accuracy of the method described.

Summary

MICRO AMOUNTS of ozone may be determined by using alkaline potassium iodide as absorbing solution. Iodine released after acidification is determined precisely and rapidly by a spectrophotometric technic wherein the absorption of the triiodide ion at 352 millimicrons is measured. Oxygen does not appreciably oxidize the reagent, and the effect of other oxidants is discussed.

Further research work is in progress on this study.

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Industrial Hygiene Foundation

THE SEVENTEENTH Annual Meeting of the Industrial Hygiene Foundation was held at the Mellon Institute in Pittsburgh, November 19 and 20. Representatives from 350 member companies of the Foundation participated in Medical, Engineering, Chemical-Toxicological, and Legal Conferences on the first day.

The main meeting, designed particularly for management, was held on November 20. The keynote address was presented by L. R. BOULWARE, Vice President, General Electric Company, on the subject "The Greater Industrial Health." He set forth the duties of industrial hygiene specialists in contributing to industrial health in the broadest sense, not only through the usual professional channels but also through the promotion of good citizenship activities with everyone within the area of their contacts at work and away from work.

DR. EDWARD R. WEEDLEIN, President of the Mellon Institute welcomed some 600 leaders in the industries and in the professions, and ANDREW FLETCHER, President of St. Joseph Lead Company and Chairman of the Industrial Hygiene Foundation, summarized the activities of the Foundation during the past year.

STATEMENT of the ownership, management, and circulation required by the Act of Congress of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233), of American Industrial Hygiene Association Quarterly published quarterly at Sheboygan, Wis. for October 1, 1952. 1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, Industrial Medicine Publishing Company, 605 North Michigan, Chicago, Ill.; Editor, Herbert T. Walworth, Lumbermens Mutual Casualty Company, 4750 Sheridan Road, Chicago, Ill.; Managing Editor, none; Business Manager, none. The owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 percent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership, or other unincorporated firm, its name and address, as well as that of each individual member, must be given.) The American Industrial Hygiene Association (a non-incorporated association); Henry F. Smyth, Jr., Executive Secretary, Mellon Institute, Pittsburgh 13, Pa. 3. The known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.) None. 4. Paragraphs 2 and 3 include, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting; also the statements in the two paragraphs show the affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner. 5. The average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the 12 months preceding the date shown above was: (This information is required from daily, weekly, semiweekly, and triweekly newspapers only.) Herbert T. Walworth, Editor. Sworn to and subscribed before me this 20th day of October, 1952. (Seal) Lowell D. Snorf, Jr. (My commission expires August 20, 1955.)

✦ Industrial Hygiene Briefs

Occupational Illnesses of Bacterial Origin

THE cleaning of the condenser tubes of a large turbo-generator to remove accumulated slime, mud, etc., which collects in the tubes as a result of the use of river water for cooling, produced a number of cases of illness. The men doing the work were required to work in confined space shooting plugs of rubber through each condenser tube with compressed air. The job was wet, dirty, and unpleasant, and it was first thought that complaints of sickness resulting from it were psychological rather than physiological.

After the third case had been reported describing the same symptoms (moderately high fever, 102°-104° F., aches, and pains of the major joints, headache, and a general feeling of malaise, with spontaneous recovery within 48 hours), investigation was made and atmospheric samples were taken in sterile water and later cultured. The cultures identified "pseudomonas aeruginosa" as the predominant bacteria present in the atmospheric samples. Pseudomonas aeruginosa (B. pyocyaneus) is an organism frequently termed the bacillus of green or blue pus. It is widely distributed in water, and air, on the skin and in the upper respiratory tract, and is often isolated from faeces. It is associated sometimes with other pyogenic organisms in abdominal abscesses. It is probably more pathogenic than has been supposed, and is sometimes the sole cause of cystitis, otitis media, mastoiditis, enteritis in children, and occasionally, even of speticaemia.* Cultures of secretions of the nose and throat taken from the workmen at the end of the shift, were also made but did not reveal the presence of pseudomonas aeruginosa but rather the presence of normal flora of the respiratory tract. Cultures were also made of the material taken from the condenser tubes and growth was so profuse with pseudomonas aeruginosa that all other growths were obscured, making other identifications virtually impossible.

A search of literature with reference to illness of this type resulting from pseudomonas aeruginosa revealed nothing.

It was then assumed that some air and/or water borne bacteria was responsible for the illness described and subsequent cleanings of the turbo-generator condenser were prefaced by a one hour period of circulation through the tubes of HTH, a compound which releases the hypochlorite ion. Upon opening the condenser, after the first of these treatments with HTH, the tubes were found to be so clean that further cleaning was unnecessary and specimens of the residual in the tubes were cultured and found to be sterile.

It was then reasoned that if sterilization with a chlorine compound resulted in cleaning of the tubes without need for mechanical cleaning that chlorination of the cooling water and subsequent filtering would probably produce the same result and allow the turbo-generator to be operated continuously without shutdown for condenser tube cleaning. This proved to be the case. Condenser cleaning after the use of the chlorine compound produced no cases of illness and this procedure was in effect for well over a year before chlorination of water was started and during that time no illness occurred.

It is, therefore, concluded that pseudomonas aeruginosa was probably responsible for the production of the illness described above and that prevention of the illness was obtained by sterilizing the condenser tubes before allowing men to become exposed to any atmospheric contamination arising therefrom.—ANONYMOUS

*Stitt, Clough and Clough: Practical Bacteriology, Blakiston Press, pp 130.

✦ Obituaries

HERBERT G. DYKTOR, Commissioner of the Division of Air Pollution Control of the City of Cleveland, died October 4, 1952, after a severe illness of about two months.

Born in Nice, France, he was educated in France, Belgium, Austria and England, completing his formal education with a Bachelor of Science Degree in Mechanical Engineering from London Polytechnic. In 1921 he came to the United States and was in the steel business for a number of years.

Becoming interested in industrial hygiene at a time when there were very few organized industrial hygiene groups in existence, he served as Chief of the Industrial Hygiene Service at St. Louis from 1932-1939, leaving that position for one as Chief Engineer with the Bureau of Industrial Hygiene of the State of Michigan. In 1944 he was asked to organize a Bureau of Industrial Hygiene for the City of Cleveland and became its first Chief. In 1947 when all the various air pollution agencies which had previously been scattered through the city government were combined under the Division of Air Pollution Control, MR. DYKTOR was appointed Commissioner to head the Division.

Having always taken an active part in the promotion of industrial hygiene and air pollution work, MR. DYKTOR was the author of a number of papers on these subjects, and he was frequently called upon to lecture to college, professional, and civic groups.

Among the numerous professional and civic organizations of which he was an active member are the following: American Conference of Governmental Industrial Hygienists, a past president; American Industrial Hygiene Association; American Public Health Association, fellow and past chairman of the Industrial Hygiene Section; Air Pollution Control Association; Society of Professional Engineers; American Society of Heating and Ventilating Engineers; and Conference of Municipal Public Health Engineers.

While his past accomplishments in the fields of industrial health and air pollution control have been worthy, he was also continually interested in new plans for the future. The fulfillment of these plans will be more difficult because of the loss of his leadership. Those who are engaged in industrial hygiene and air pollution control work will sorely miss him.

DR. PAUL A. NEAL, a Medical Director with the U.S. Public Health Service, assigned as chief of the laboratory of physical biology, National Institute of Arthritis and Metabolic Diseases, died of a heart ailment at his home October 13, 1952. His age was 51.

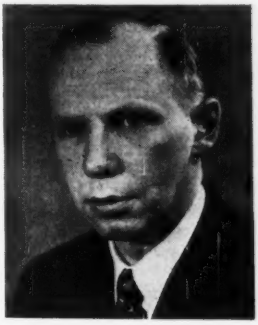
DR. NEAL was born in West Point, Tennessee. He received his M.D. degree from Vanderbilt University in 1927 and entered the Public Health Service the following year. From 1929 to 1933 he was attached to the United States consulates in Germany, Italy, Denmark, Ireland and Poland. From 1936 to 1947 he was chief of industrial hygiene studies at the National Institute of Health. He served as head of the physical biology laboratories from 1947 to the present, directing medical research in such fields as molecular biophysics, low-energy and nuclear radiation biology, and physiological physics.

DR. NEAL made many contributions in the industrial hygiene field, particularly in industrial toxicology. Recently he directed field and laboratory research clarifying the effect of DDT on human lungs.

In addition to membership in AIHA, DR. NEAL also was a member of the American Medical Association, American Public Health Association, American Association for the Advancement of Science, Washington Academy of Sciences, Association of Military Surgeons, and many others. He was the author of more than 100 scientific articles.

✦ President's Page

The Industrial Hygiene Laboratory



SO BASIC is the work of the industrial hygiene laboratory and so necessary are the results of laboratory techniques in the formation of evaluations with respect to employee health maintenance, that it seems unnecessary to make comment. Indeed, wherever is found the headquarters for industrial hygiene, there nearly always is found a chemical laboratory around which revolves the work of the entire industrial hygiene group. Sound reasons for establishing separate laboratories in industrial hygiene are recognized. They include the fact that new techniques are needed both for accurately obtaining samples of work-place air and for accurate and precise analysis of these samples.

Early in the establishment of industrial hygiene groups, it was recognized that a specially designed and equipped laboratory was needed for this type of work. Hence, the development of special skills in designing and testing equipment to capture trace quantities of airborne substances and for accurate quantitative chemical and physical analysis of material so collected. A new type of laboratory was thus formed which made use of special apparatus and new chemical techniques. Similar techniques, of course, were needed and are now used by the toxicologist that he may determine accurately the magnitude of exposure in his small animal chamber work or in checking dosage levels.

While no exact laboratory counterpart exists in the large research laboratories of the country, nevertheless fundamental and basic analytical theories therein developed are adopted by the industrial hygiene chemist.

Currently the development of instrumentation and analysis in this field is rapidly expanding as he keeps abreast of the host of new chemicals which are entering the industrial scene. The apparent natural inquisitiveness of the industrial hygiene chemist finds free outlet in this new field of study. It soon became apparent that the laboratory of industrial hygiene was the obvious location for the referral of all problems in the field of air pollution control.

At first our chemists were pleased when they could determine the presence of substances in their samples in terms of parts per thousand parts of air. Soon their reports were in terms of parts per hundred thousand, then parts per million. Now we occasionally hear of analytical results expressed as parts per billion. Accompanying this inquisitiveness has come introspection, the result of which has led to the desire for standardization of techniques between one laboratory and another. This work is continuing and trace samples of reference are traveling from laboratory to laboratory as a part of the standardization program. This important and fundamental work of both the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists committees now developing satisfactory and successful standards of industrial hygiene laboratory procedure is most commendable.

There has come into existence in the State of California, laws and regulations relating to the operation of clinical laboratories. The question arises as to whether or not industrial hygiene laboratories are also included in the very general and broad coverage of this law. It is not at all clear that the existence of an industrial hygiene laboratory was known or considered by those writing the definition for the clinical laboratory law.

It behooves industrial hygiene chemists about the country to become familiar with the provisions of the California law that

establishes the qualifications of personnel, defines activities and provides a procedure for license and license fees. Our introspection might well include this subject.

The American Industrial Hygiene Association's Northern California Local Section and Southern California Local Section have been considering the legislation for some time. They now request opinions from industrial hygienists elsewhere in the country on the questions raised by the California law. These two Local Sections have formed a joint committee to investigate the meaning of the law in terms of industrial hygiene. Quite naturally, they wonder if such legislation would be beneficial or detrimental to our work. The obvious question arises, "Is there need for self discipline or self regulation by industrial hygiene laboratories?" Please express your opinions on this subject to our California membership.

—WILLIAM R. BRADLEY

✦ News of Local Sections

Utah Section

ON SEPTEMBER 17, 1952, the Utah Section met at the U.S. Public Health Service Laboratory. "Industrial Ventilation" was the program topic for the evening.

R. G. GAW, U.S. Steel, chose "Ventilation for Laboratories and Coal Handling" as his topic, and E. OLSEN, U.S. Steel, covered "Problems in Coal Mine Ventilation." K. W. NELSON, American Smelting and Refining Company, ALTON W. HUFFAKER, U.S. Smelting, Refining and Mining Company, and JOHN F. KNUDSEN, Kennecott Copper Corporation, contributed most adequate discussions of the "Control of Dust and Fumes in Smelting and Refining." MESSRS. NELSON, HUFFAKER AND KNUDSEN used slides in the course of delivering their respective portions of the discourse.

The Utah Section extends its warmest welcome to LEWIS J. CRALLEY, newcomer to Salt Lake City. Mr. Cralley assumes the duties of Director of the Western Branch, Division of Occupational Health, United States Public Health Service at Fort Douglas.

Northern California Section

AT THE SEPTEMBER 16, 1952 meeting of the Northern California Section, MISS PATRICIA WARR surveyed "California's Experience in Occupational Diseases and Fatalities from Carbon Tetrachloride." The committees on a plan for accrediting industrial hygiene laboratory work made their report and this was discussed by the membership.

Ohio Valley Section

ON SEPTEMBER 17, 1952, the Ohio Valley Section met in the Lecture Room of Kettering Laboratories. MISS VICTORIA M. TRASKO, Public Health Advisor, Division of Occupational Health, U.S. Public Health Service, delivered an informative and interesting talk on "Industrial Health Conditions in South American Countries."

New Jersey Section

THE FIRST fall meeting of the New Jersey Section was held October 16, 1952, at Newark, New Jersey. DR. EDWIN MERRILL, Chief of the Bureau of Cancer Control, New Jersey State Department of Health, presented an address on the "Preliminary Report of the New Jersey Occupational Cancer Survey."

K. R. DOREMUS, Merck and Company, and J. F. MELLOR, JR., American Cyanamid Company, have recently transferred their membership from the Philadelphia Section to the New Jersey Section.

As an affiliate of the Technical Societies Council of New Jersey, the New Jersey Section as co-sponsor of a symposium on *Air Pollution* which was held at the Essex House, Newark, New Jersey, on November 17, 1952. DR. MIRIAM SACHS of the New Jersey Section spoke on the subject "Degree of Air Pollution Permitted."

Chicago Section

LOUIS CHESKIN, Director, Color Research Institute of America, was the speaker at the September 3, 1952, meeting of the Chicago Section. In his talk "Color in the Industrial Plant," MR. CHESKIN emphasized the psychological effect of color in our environment, and brought out the importance of color for safety, color for efficiency, and color for morale in industry. He reported some of the outstanding findings from experiments conducted by Color Research Institute and offered case histories of the tremendous effect of color in our daily lives.

Due to the Elevator Operators' and Starters'

strike, the section did not meet on October 1, 1952.

At the meeting of November 5, 1952, HERBERT T. WALWORTH, Director of Industrial Hygiene, Lumbermens Mutual Casualty Company, gave a "Brief Summary of the National Noise Abatement Symposium."

The major address was given by CHARLES A. LOWE, General Manager, Maico Hearing Instruments, Inc., who discussed "Rapid and Accurate Industrial Hearing Tests." Through the liberal use of slides, MR. LOWE acquainted his audience with audiograms and the anatomy of the human ear.

The first issue of the Chicago Section Newsletter was mailed to members and has had an enthusiastic reception, and membership booklets were distributed to section members.

New England Section

THE ANNUAL Meeting of the New England Section was held at the Massachusetts Institute of Technology on November 14, 1952. The morning session consisted of a program of the following talks:

"Removal of Soluble Gases and Particulates from Air Streams (with special reference to Fluorides)" by EDWARD BERLY, DR. MELVIN FIRST and DR. LESLIE SILVERMAN, Department of Industrial Hygiene, Harvard School of Public Health, Boston, Massachusetts.

"Use of CO_2 Analysis in Carboxide Fumigations" by CDR. HARRY J. ALVIS, MC USN and LT. EUGENE C. STONE, MC USN, Squadron Medical Officers for Submarine Squadrons Ten and Two Atlantic Fleet respectively at the time.

"The Usefulness of Calcium di-Sodium Ethylene Diamine Tetra Acetate in the Treatment of Lead Poisoning" by DR. HARRIET L. HARDY, Occupational Medical Service, M.I.T., Cambridge, Massachusetts, and DR. HARVEY B. ELKINS, Division of Occupational Hygiene, Massachusetts Department of Labor and Industries.

"Exposure of Connecticut Tobacco Growers to Parathion" by GRANT H. VANCE and REINHOLD A. SCHAEFER, Bureau of Industrial Hygiene, Connecticut Department of Health, Hartford, Connecticut.

"Urinary Excretion of Paranitrophenol following Exposure to Parathion" by DR. JAN LIEBEN, DR. RUDOLPH K. WALDMAN and LEONARD KRAUSE, Bureau of Industrial Hygiene, Connecticut Department of Health, Hartford, Connecticut.

"Carbon Monoxide Toxicity in Submarine Operations, A Case Report." CDR. HARRY J. ALVIS, MC USN Staff and C. W. TANNER, HMC (SS) USN, Submarine Development Group Two USN Submarine Base, New London, Connecticut.

"Radiological Safety at M.I.T." by SAMUEL LEVIN, Radiological Safety Officer, Occupational Medical Service, M.I.T.

The Business Meeting closed the morning's activities. A two-hour tour of M.I.T. Radiological Facilities was held in the afternoon. This was followed by a Discussion and Question Period on Radiological Safety, conducted by SAMUEL LEVIN.

Southern California Section

THE ANNUAL Meeting of the Southern California Section was held at The Golden Pagoda on November 13, 1952. "Dust Evaluations in the Vicinity of Cement Plants" was discussed by JOHN SAUER and FRANK STEVENS.

H. L. MOTLEY, M.D., Ph.D., delivered a talk on "Pulmonary Function Studies." In addition to the excellent program, the election of 1953 officers was held. Ballots were mailed to all members of the Section and those unable to attend the dinner meeting were permitted to vote by mail.

Texas Section

THE ANNUAL Meeting of the Texas Section was held September 26, 1952, in Houston, Texas, in conjunction with the regional Gulf Coast Conference on Industrial Health, of which this Section is co-sponsor. The scientific program was provided by the Conference.

In view of the establishment of the North Texas Section AIHA, the name of the Texas Section was changed to the Gulf Coast Section AIHA. The State has been geographically divided equally between the two sections, along an east-west line.

The following members were elected for the coming year: President—MARTIN C. WUKASCH; President-Elect—DR. C. U. DERNEHL and Secretary-Treasurer—J. W. HAMMOND.

Michigan Industrial Hygiene Society

DR. WILLIAM G. FREDRICK, Director, Bureau of Industrial Hygiene, Detroit Department of Health, addressed the Michigan Industrial Hygiene Society, October 6 on "Health and Safety in German Industry." The discussion covered safety codes and laws; the policy of equal participation of labor and management in planning and executing health and safety programs; silicosis treatment and prevention; and research facilities in Germany. In addition, DR. FREDRICK showed some of the pictures he had taken while in Germany.

At a meeting on November 6, VINCENT F. MCAULIFFE, Deputy Commissioner of Workmen's

Compensation, spoke on "Present Trends in Workmen's Compensation." MR. MCAULIFFE answered many specific questions from the audience and included some discussion on the value of industrial hygiene surveys and information in compensation cases.

Western New York Section

THE WESTERN New York Section began the current season with a meeting on September 20. Twenty-five members visited the plants and shops of the Pfaudler Company and were addressed by ELBERT A. SANFORD, Research Director of the Pfaudler Company and a member of the local section, on the subject of the origin and history of the Company. Following the talk, the group was guided through the plant.

The general policy has been established for the Section to acquaint members with the various industries operating within the Section's geographical area.

Greater St. Louis Section

A MEETING of the Greater St. Louis Section was held in the Grand Maria Dining Room in East St. Louis on November 18. DR. V. P. SIEGEL, Industrial Physician for the Aluminum Ore Company, was the principal speaker and chose as his subject "Correlation of Industrial Medicine and Industrial Hygiene Programs."

Metropolitan New York Section

THE METROPOLITAN New York Section met October 27 and heard an interesting discussion of the "Status of Industrial Noise" presented by DR. CHARLES R. WILLIAMS, Director of Applied Research in the Loss Prevention Department of Liberty Mutual Insurance Company. Fifty-five members and guests were present at the meeting and 34 persons attended the dinner which preceded the meeting.

The results of a questionnaire asking members views on programs and arrangements for local section meetings have been tabulated. Monday is the preferred meeting night and the chosen topics are Medical and Engineering Aspects of Industrial Hygiene.

✦ *Classified*

Positions Available

Research project leader—to conduct and supervise research on particles and aerosols. Salary $4205 to $7040; Maryland.

Industrial hygienist—chemical company, New York City, with plants located in several states; salary open.

Industrial hygiene chemist—electrical equipment company, New York State. Minimum of five years experience in air sampling, analytical work, plant surveys; salary dependent on experience.

Industrial hygiene engineer with experience in air pollution control. Salary $4620 increasing over five-year period to $5775. For details, address: State Department of Health, Division of Industrial Health and Air Pollution, William F. Reindollar, Sc.D., Chief, 2411 N. Charles Street, Baltimore 18, Maryland.

Industrial health engineers (2): Minimum four years experience, public health engineering—eligible for professional registration. Salary $481-584 in 5% steps. Retirement program. For details, address: Fred R. Ingram, Chief Engineer, Department of Occupational Health, Cowell Memorial Hospital, Berkeley 4, California.

Biochemist for toxicological research—Ph.D. or M.S. in chemistry with or without experience. For details, address: Dr. Henry F. Smyth, J. Mellon Institute, 4400 Fifth Avenue, Pittsburgh, Pennsylvania.

Industrial hygiene engineer (Public Health Engineer I, or II if well qualified), salary range $336 for I, $426 to $513 for II. For details, address: Kenneth Y. Flocke, Industrial Hygiene Section, Oregon State Board of Health, 1400 Southwest Fifth Avenue, Portland, Oregon.

Personnel Available

The AIHA Personnel Placement Committee has qualified applicants for all phases of industrial hygiene. For additional information on positions or applicants write: Frederick S. Mallette, Chairman, AIHA Personnel Placement Committee, % American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.

The Manufacturing Chemists' Association has released Manual Sheet TC-1, a 12-page booklet which discusses in detail the recommended practice for unloading sulphuric acid or mixed nitric and sulphuric acids from tank cars. This publication is a revision and broadening of the previous edition which was issued in 1941. It is available from the Association's headquarters at 246 Woodward Building, Washington 5, D.C. at 20c per copy, postpaid.

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